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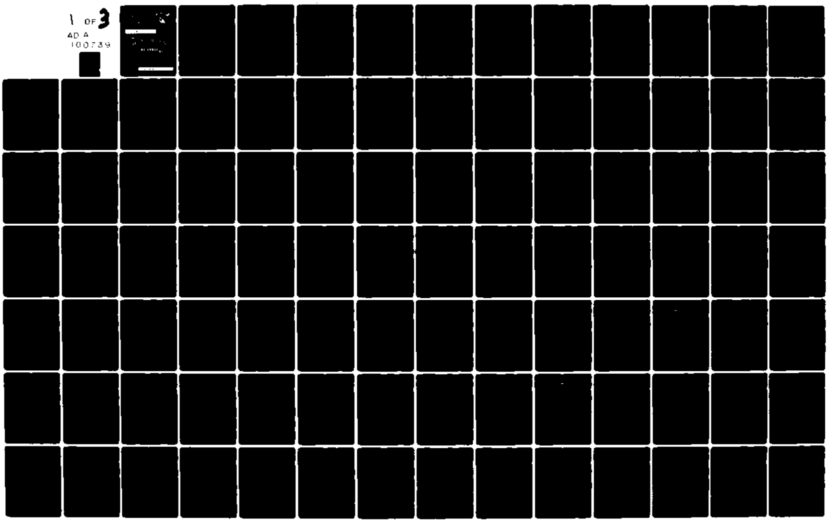

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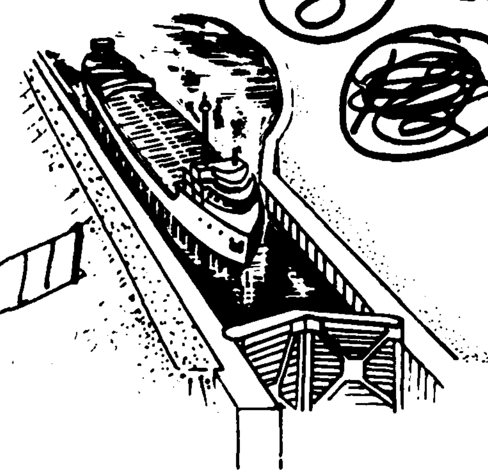

LEVEL III

REVIEW *of* REPORTS

on

LAKE ERIE - LAKE ONTARIO WATERWAY N.Y.

APPENDIX B

GEOLOGY, SOIL, AND MATERIALS

U.S. ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT

OCTOBER 1973

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The purpose of this review is to examine the conclusions from the environmental, engineering and economic studies of the construction of a water way between Lake Erie and Lake Ontario in the United States. This report will also serve as a basis for further action by Congress.

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REVIEW OF REPORTS
ON
LAKE ERIE - LAKE ONTARIO WATERWAY

APPENDIX B
GEOLOGY, SOIL, AND MATERIALS

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LAKE ERIE - LAKE ONTARIO WATERWAY GEOLOGY AND SOILS APPENDIX

INTRODUCTION AND PURPOSE

B-1. The proposed Lake Erie-Lake Ontario Waterway lies in a general north-south direction connecting the two lakes and is divided into the overland and the Niagara River sections. The overland section connects Lake Ontario with the Niagara River near the city of North Tonawanda. This section with four 80-foot high locks has two possible alignments, A-1 and C-2. The Niagara River section is in the river and joins into Lake Erie via a lock with a 5-foot high lift and a canal at Squaw Island. Due to the foundation requirements of the two sections, emphasis will be placed on the overland section in this Appendix.

The purpose of the Appendix is to describe the geologic conditions and their effect on the canal and lock areas of the proposed waterway. The Appendix will stress the following:

a. The characteristics of the overburden and bedrock.

b. The geologic and soil investigations and tests performed to date.

c. The foundation conditions at the lock sites.

d. The sources of construction materials.

REGIONAL GEOLOGY

B-2. Physiography

The region of the Lake Erie-Lake Ontario Waterway is located in

the western portion of the Erie-Ontario physiographic province of New York, which is in the northeastern portion of the Central Low-lands physiographic province of the Interior Plains, physiographic division. It is bordered on the north by Lake Ontario, on the west by Lake Erie and the Niagara River, and on the south by the Allegheny Plateau (Fig. B1). Within this region are three plains, Ontario, Huron, and Erie, separated by the east-west striking Niagara, Onondaga, and Portage Escarpments. Alignments A-1 and C-2 of the overland section are shown on Figure B2. The elevation above mean sea level of the region ranges from 244 feet at Lake Ontario to 1,500 feet along the Portage Escarpment. The relief between Lake Ontario and Lake Erie is 326 feet. Over one-half of that relief along the proposed waterway is located at the Niagara Escarpment.

B-3. Stratigraphy

In the lowland, the age of the bedrock follows a Paleozoic sedimentary sequence and ranges from the Upper Ordovician through the Upper Devonian. This sequence is shown on a geologic map (Fig. B3). A generalized section for the pertinent formations, which are from the Upper Ordovician System through the Bertie Group of the Upper Silurian System, is shown on Plate B1. This section was based partly on data from Fisher (1960).

The Queenston Shale, which is the bedrock for the Ontario plain, is Upper Ordovician in age and 1,200 feet thick in western

New York. The interbedded shales, siltstones, and sandstones of the Medina Group are the rocks of the Lower Silurian. The Middle Silurian strata are composed of alternating beds of shale, sandstones, and limestones of the Clinton Group and dolomite-limestone and dolomites of the Lockport Group. The gypsiferous shale of the Salina Group and the shales and dolomite of the Bertie Group together with the Akron Dolomite make up the Upper Silurian strata. There are no Lower Devonian rocks in the region. The Middle Devonian rocks are made up of the Onondaga Limestone and the shales of the Hamilton Group and underlie Upper Devonian shales.

Outcrops of lowland bedrock are found along streams and along certain reaches of the shoreline of Lake Erie and Lake Ontario. The more resistant formations are exposed along the Niagara and Onondaga Escarpments. A complete sequence from the Queenston Shale of the Upper Ordovician age through the Lockport Group of the Middle Silurian age can be observed along the Niagara Gorge.

B-4. Geologic Structure

The strata of the bedrock in the lowlands have a general dip of approximately $1/2^{o}$ to the southeast and a strike subparallel to the face of the escarpments. Only minor undulations have been found in the rocks of the area, such as along certain road cuts in western New York. Major folding, however, occurs in the Allegheny Mountains to the south. One large fault running from Clarendon to Linden, NY, which has a throw of over 100 feet, has been noted by Chadwick (1919).

This normal fault strikes in a north-south direction and dips to the west. The fault is approximately 40 miles east of the proposed waterway. Its approximate location and extent is shown on Figure B3. Numerous small thrust faults along with superficial faults caused by surface agents or the removal of salt or gypsum in the underlying bed have been reported in the region.

As of this date, there are no known recent comprehensive published reports on jointing in western New York. However, joint studies for the surrounding areas of central New York and northern Pennsylvania have been published by Parker (1942). A joint survey was conducted by the Buffalo District for the American Falls Study approximately 10 miles from where the alignment and the Niagara Escarpment intersect. The preliminary analysis indicated at least two joint sets in the Lockport Dolomite. A high angle N60°E - N80°E joint set appears to be a pronounced set with a secondary set trending N10°W to N20°E. Also at the American Falls, near vertical sheeting joints in the Rochester Shale were subparallel to the face. It can be expected that sheeting joints have developed in the Rochester Shale along the Niagara Escarpment.

Evidence of convergence and uplift in man-made cuts in the Lockport and Rochester Formations indicate that horizontal and vertical active stresses are present in the rock. A study by Rose (1951) of the Niagara Falls area reported numerous cases of rock movement in the region both east and west of the proposed

waterway. At Rochester, NY, for example, all the original bridges across the Barge Canal at the western limit of the city are known to have converged. At Lockport, NY, a 30-foot cut for the Barge Canal converged 9 inches in 25 years. Also in Lockport, NY, at the bottom of the Barge Canal, the Rochester Shale is rising, and it is necessary to remove rock every year in order to maintain the proper depth of the Canal. Near Niagara Falls, Ontario, a time dependent convergence of 4 inches was measured in a wheel pit for the Niagara Mohawk Power Plant. One hundred and fifty feet of Lockport Dolomite and 30 feet of Rochester Shale were excavated for the wheel pit. Further examples of rock movement are found in the report. Some of Rose's conclusions are:

a. Maximum stress direction appears to be in a general east-west trend in the Niagara Falls-Lockport area.

b. A much greater movement occurs in the Lockport Dolomite than in the Rochester Shale.

c. The maximum rate of rock movement probably occurs near the time of excavation and gradually diminishes.

Further examples of rock displacement as a result of load release due to excavation are reported by Hogg (1958).

Rebound of unexcavated land masses due to glacial loading and unloading are found in this region. One example of this type of uplift is the tilting of some beach ridges, indicating rebound after deposition.

B-5. Seismicity

The Environmental Science Service Administration (ESSA) prepared a seismic risk map in 1969 dividing the continental United States according to occurrences of earthquakes. These divisions or zones are based on intensities of earthquakes and geological considerations and are numbered 0 to 3. The Erie-Ontario lowland is in the zone 3 area, where major destructive earthquakes may occur. Epicenter locations of earthquakes in the area since 1857 have been recorded by the ESSA and others. These locations and their intensities, using the Modified Mercalli Intensity Scale of 1931, are given on Table B1 and shown on Figure B4. This scale, a local measure of seismic effects on people and objects in any affected area, is a result of the energy-release of the earthquake, the distance, the geology, and the structural properties of buildings. The scale ranges from one to twelve in intensity. The highest intensity earthquake in the region registered an eight on the scale. The shallow excavation for the overland Canal would have no appreciable effect on the occurrence of seismic disturbances. The design of the structures of the waterway should take into account the earthquake factor.

B-6. Geologic History

The topography of the area consists of a series of gentle rolling plains interrupted by east-west striking escarpments. The simple geologic structure and the erosional feature of the bedrock along with the complex glacial erosion and deposition produces an interesting geologic history.

The age of the bedrock ranges from Ordovician to Upper Devonian. The strata dip approximately 33 feet per mile to the southeast. The rock formations are interbedded shales, siltstones, sandstones, limestones, and dolomites of various thickness and sequence. Differential erosion left the more resistant rocks as escarpments, separating the low irregular surfaces of the more erodible rocks. The bedrock in the area has greatly influenced the Pleistocene geology.

During the Pleistocene age, the area was subjected to four major advances of glacial ice alternating with warm periods. Each advance scoured the bedrock and incorporated and rearranged the deposits of its forerunner; therefore, only the last major advance (Wisconsin) can be totally recognized. Glacial till was deposited in some areas as terminal and ground moraines covering the bedrock. The retreat of the glaciers was accompanied by vast amounts of meltwater. Huge lakes were formed in the scoured lowlands and were ancestors of the Great Lakes. Within the lakes, in some areas, silts and clays were deposited over the glacial till. The Niagara River channel drained the waters from early Lake Erie into Lake Iroquois. Further decrease in the lake levels introduced glacial Lake Tonawanda in the lowland between the Onondaga and Niagara Escarpments. It drained to the north over the Niagara Escarpment. Visible channels cut into the escarpment are found at Lockport, Gasport, Lewiston, Medina, and Holly, NY. Some buried channels may exist throughout

the escarpment. During part of the stage of Lake Iroquois, water extended to the base of the Niagara Escarpment and formed sand beach deposits. Complete and detailed discussions of the complex Pleistocene history are given in Calkin (1966), Kindle and Taylor (1913), and Spencer (1907).

B-7. Ground Water

The presence of ground water is dependent on the permeability of the materials involved. The aquifers in this area are in both overburden and rock. The overburden of the Ontario, Erie, and Huron plains consists primarily of glacial till and lacustrine clays, which are generally low-yielding aquifers. The Lockport, Camillus, and Onondaga Formation are the three major aquifer units in rock. The Lockport Dolomite and the Onondaga Limestone have water flowing through fractures, joints, and open bedding planes and yield as much as 100 gpm. The Camillus Shale has water flowing through solution cavities along gypsum and salt beds and yields as much as 1,200 gpm. The rest of the formations in the area is low-yielding aquifers and are considered impermeable (LaSala and others 1964).

INVESTIGATIONS PERFORMED

B-8. Field Investigations

Subsurface explorations were performed from 1963 through 1967 to determine the character and conditions of the overburden and the bedrock for the Lake Erie-Lake Ontario Waterway project. The drilling

was performed by the Detroit, Mobile, and Buffalo Districts, Corps of Engineers and by Empire Soils Investigation, Inc. These explorations included drilling and sampling in overburden with augers, undisturbed and drive samplers into rock with six-inch and NX-size core barrels. The locations of the explorations are shown on Plates B2, B3, B4, B5, and B6. The thickness of overburden, depth drilled into rock, and other pertinent data on the explorations are given on Table B2.

During the period from 1963 through 1965, a drilling program was performed along the original waterway alignments. There were 24 borings located along Alignment A of the overland section and six borings along the lock site at Squaw Island of the Niagara River section. These borings were taken to determine the characteristics and depths of the overburden, the conditions of the bedrock along the alignment, and to obtain samples for testing. In overburden, standard splitspoon drive samples were taken in 26 borings. Three-inch shelby tube undisturbed samples were taken in five of those borings. Twenty-three borings out of the 30 that were drilled into the rock were NX-size with the remainder of the borings 6-inch size. There were 403 probings to determine the top of rock in the overland section. This was done by drilling a solid steel rod to refusal, which was assumed to be the overburden bedrock contact. A rock contour map based on these probings and supplemented by the boreholes is shown on Plate B7.

In late 1965, the overland section alignments were changed to

the existing Alignment A-1 and C-2. Initially, one 6-inch core boring was drilled along Alignment A-1. That boring revealed several soft clay zones (1.6 feet to less than 0.1 foot thick) below the assumed sound rock line in the Queenston Shale. Subsequently, a total of 15 core borings was drilled to gather data on overburden and rock. In overburden, standard splitspoon drive samples were taken in four borings, and 3-inch shelby tube undisturbed samples were taken in four borings. Of the 14 borings drilled into rock, 11 were NX-size and three were 6-inch size. Continuous Queenston Shale core was obtained to depths ranging from 85 to 135 feet in the bedrock. Pressure testing was performed in bedrock. These borings were located along the first three locks of Alignment A-1.

B-9. Laboratory Testing

Laboratory tests were performed on the Queenston Shale and soil samples along the overland section to determine criteria for shear, bearing, and consolidation. Tests were also performed on the Queenston Shale to determine the effects of cylic loading due to the filling and emptying of the locks. In 1963, samples of the Queenston Shale from UDC-5A were prepared in suites, and samples from each suite were sent to NCD (North Central Division),ORD (Ohio River Division), and SWD (Southwestern Division) Laboratories. The tests performed by SWD were mainly torsional shear. Due to the difficulty of interpretation, the torsion shear test is no longer performed by SWD, and the results have not been included. In 1966,

overburden samples from RUDC 16, RUDC 17B, RUDC 28, and RUDC 29 were tested by NCD Laboratory. In 1968, consolidation, permeability, Atterbergs, and one point triaxial compression tests were performed on undisturbed samples of overburden from Borings U66502, 67511, AUDC 67515, and AUC 67516. A summary of all the laboratory testing data is on Table B3. The basic laboratory test data is in Supplement one of this Appendix and is available for review at the U. S. Army Engineer District, Buffalo, upon request.

Cyclic loading tests were performed on 6-inch diameter core samples of Queenston Shale. The Concrete Division, WES (Waterways Experiment Station), performed petrographic and chemical analyses on the shale and chemical analysis of the water used during the testing. The equipment was designed by NCD Laboratory. The samples used for these tests were from Boring RC66501. The cyclic loading tests were performed on saturated samples in triaxial equipment for a year. The specimens were then tested to failure without drainage under a lateral pressure of one ton per square foot. Uncycled specimens were tested to failure by the same method. WES also performed petrographic and chemical analyses on samples of the shale and water after testing. Neither the length of the cycles nor frequency of the cycling had any apparent effect on the strength of the shale. However, based on the results of the tests, it was determined that for a factor of safety of three, the Queenston Shale should not be loaded over 33 tons per square foot. For details of the program see Davis (1970).

LOCAL GEOLOGY

B-10. Topography

The elevations between the Ontario plain and the Huron plain vary considerably along the proposed waterway. The Ontario plain is nearly level and has an average elevation of 250 feet above mean sea level. The surface slopes northward from elevation 400 feet near the base of the escarpment, which separates the two plains and is divided into the lower and upper escarpment along the proposed waterway, due to differential erosion of certain rock formations. The Huron plain, which slopes westward, is also nearly level and has an average elevation of 650 feet at the Niagara Escarpment to 600 feet at Squaw Island. The surface elevation of the Niagara River is about 570 feet. A geologic profile along the overland section is shown on Plates B8, B9, and B10.

B-11. Overburden

Overburden information was obtained from field investigations and previous studies (Kindle and Taylor, 1913). The overburden of the Ontario plain along the proposed waterway is generally glacial till of the Wisconsin age. The till blankets the Queenston Shale and consists of a clay silt matrix with some sands, gravels, and boulders. Lacustrine deposits of glacial lakes Lundy and Iroquois are found in favorable localities over the till. These stratified clays and silts are found near the shores of Lake Ontario and in an irregular

four square mile area near the town of Ransomville. The Lake Iroquois beach ridge is located along Route 104 and is 10 to 30 feet above the adjacent ground surface. Data from boreholes indicate a buried basin along the base of the escarpment. The materials in the basin range from impermeable clays and silts to pervious sands and gravels. The overburden thickness of the Ontario plain along the alignment averages 30 feet and ranges from 10 feet to 120 feet.

The overburden of the Huron plain along the overland section of the waterways is mainly made up of glacial till and lacustrine deposits. The till covers most of the bedrock of the Huron plain and has generally the same characteristics as the till of the Ontario plain. Extensive deposits of lacustrine silts and clays, from both Lake Lundy and Lake Tonawanda, overlie the till and are found four miles south of the escarpment to the Niagara River. The thickness of the overburden averages 23 feet and ranges from 3 feet to 50 feet. West of Sanborn, NY, for approximately 12,000 feet along the alignment, the thickness of the overburden ranges from 3.0 to 9.0 feet. Detailed soil profiles along the overland section are shown on Plates B11 through B18.

The overburden of the Huron plain at Squaw Island of the Niagara River section has an average thickness of 65 feet. North of the International Bridge, the overburden is made up of sands and gravels and has a thickness ranging from 45 to 65 feet. South of the

bridge, the material consists of fill from the garbage dump underlain by a reddish, silty clay and has a thickness ranging from 60 to 90 feet. A soil profile along the lock at Squaw Island is shown on Plate B19.

B-12. <u>Stratigraphy</u>

The bedrock of the lowland along the proposed waterway is made up of rocks ranging in age from Upper Ordovician through Middle Devonian.

The Queenston Shale represents the Upper Ordovician strata in the Ontario plain. Although the formation is approximately 1,200 feet thick, only the upper 200 feet are visible in the lowlands. The shale which is not exposed along the alignment, weathers readily into blocky chunks when exposed to the atmosphere. The Queenston, which is technically classified as a claystone, is generally maroon in color and contains some green discontinuous bands and nodules. It has massive bedding and is soft to moderately-hard. The shale is indurated (cemented with calcareous material) and is made up chiefly of the clay minerals illite, chlorite, kaolinite, and montmorillonite with some quartz. The formation contains occasional slickenside compaction planes. Soft zones were found along the alignment down to 100 feet in the shale. The Queenston Shale will be the foundation rock for four of the locks along the waterway.

The Whirlpool Sandstone, which is the basal unit of the Medina Group and of the Lower Silurian age, overlies the Queenston Shale

unconformably. The formation outcrops at the base of the lower escarpment along the alignment and is approximately 20 feet thick. It is a light-gray to white, medium- to massive-bedded, moderately-hard, medium- to coarse-grained quartzitic sandstone. The sand grains, strongly cemented by silica, are well-rounded and frosted. There are occasional inclusions of green shale scattered throughout the sandstone.

The Power Glen Shale of the Medina Group rests on the Whirlpool conformably. The shale, which does not outcrop along the alignment, weathers quite readily when exposed. The thickness of the formation at the alignment site is approximately 35 feet. The Power Glen is a grayish-green to dark-gray, laminated, moderately-hard shale. Some siltstone beds and stringers of silty limestones and dolomite are present. The major constituents of the rock are quartz and the clay minerals, illite and chlorite.

The Grimsby Sandstone of the Medina Group overlies the Power Glen Shale conformably and is not exposed along the alignment. Although portions of the Grimsby have been used as curbstones for the city of Buffalo, it generally weathers readily upon exposure to the atmosphere. The formation along the alignment is approximately 50 feet thick and is generally a pink- to dark-red sandstone and siltstone, interbedded with shale. The sandstone is fine to medium grained and is well cemented; the siltstone and shale vary from soft to moderately hard.

The Thorold Sandstone is the uppermost unit of the Medina Group and rests conformably on the Grimsby Sandstone. The formation that outcrops along the alignment at the lower escarpment is approximately 6 feet thick. The Thorold is a light- to greenish-gray, medium- to massive-bedded, hard, very fine-grained orthoquartzitic sandstone. The sand grains are cemented with silica and are subangular to angular in shape, with green shale partings occurring throughout the sandstone.

The Neahga Shale, which is the basal unit of the Clinton Group and of Middle Silurian age, rests on the Thorold Sandstone conformably. The shale, which weathers very rapidly and is not exposed along the alignment, is approximately 6 feet thick. This greenish-gray, platy, soft, dense, shale has a waxy feel and appearance. Illite, the dominant clay mineral present with quartz, is the most abundant non-clay mineral.

The Hickory Corners Limestone Member of the Reynales Limestone in the Clinton Group overlies the Neahga Shale conformably. Although the member is resistant to weathering and is 5 feet thick, it is not exposed along the alignment. It is a light- to medium-gray, argillaceous, thin-bedded, very fine-crystalline, moderately-hard limestone. The limestone has numerous wavy shale partings and bands that produce a nodular appearance.

The Irondequoit Formation of the Clinton Group overlies the Hickory Corners Member of the Reynales Limestone unconformably.

The formation is resistant weathering and is the caprock for the lower escarpment at the alignment. It has two members, (in ascending order) the Rockway Dolomite Member and the Upper Limestone Member.

a. The Rockway Member: light- to brownish-gray, thin- to massive-bedded, argillaceous, fine-crystalline, moderately-hard interspersed with occasional gypsum nodules, thickness approximately 9 feet.

b. The Upper Member: light-gray with a pinkish tint, medium- to massive-bedded, coarse-crystalline, moderately-hard, occasional vugs, thickness approximately 9 feet.

The Rochester Shale in the upper unit of the Clinton Group overlies the Irondequoit Formation conformably. The shale, which weathers rapidly when exposed to the atmosphere, is not exposed along the alignment. The formation is a medium- to dark-gray, laminated, moderately-hard shale. The thickness of the shale at the alignment is approximately 62 feet. The major constituents of the shale are quartz and the clay mineral illite. There is a 6-foot argillaceous dolomite bed near the middle of the formation.

The Lockport Dolomite of the Lockport Group rests conformably over the Rochester Shale. The dolomite is resistant to weathering and is the caprock for the upper escarpment. It is also the bedrock for the northern area of the Huron plain of the overland section. The formation consists of five members which (in ascending order)

are named DeCew, Gasport, Goat Island, Eramosa, and Oak Orchard. The total thickness of the formation along the alignment varies due to its irregular eroded surface on the Huron plain. The general characteristics of the Lockport Dolomite members are:

a. DeCew Dolomite Member: medium- to dark-gray, thin- to medium-bedded, argillaceous, fine-crystalline, moderately-hard, angular shale partings are common, thickness approximately 10 feet.

b. Gasport Limestone Member: light- to medium-gray, massive, stylolitic shale partings, fine- to coarse-crystalline, moderately-hard, vuggy, thickness approximately 18 feet.

c. Goat Island Dolomite Member: light- to dark-gray, thin- to massive-bedded, stylolitic shale partings in middle, chert nodules in upper, fine- to coarse-crystalline, moderately-hard, pitted and vuggy, thickness approximately 26 feet.

d. Eramosa Dolomite Member: medium-gray to brown, thin- to medium-bedded, stylolitic shale partings, fine-crystalline, moderately-hard, thickness approximately 14 feet.

e. Oak Orchard Dolomite Member: medium-gray to brown, thin- to thick-bedded, stylolitic shale partings, fine-crystalline, moderately-hard, thickness approximately 14 feet.

The Camillus Shale of the Salina Group and of the Upper Silurian System overlies the Lockport Formation conformably. The shale that is not exposed at the alignment is assumed to weather readily. Its total thickness is approximately 400 feet. The

formation is the bedrock for the southern area of the overland section and most of the Niagara River section. The Camillus is predominantly a brownish-gray, thin- to massive-bedded shale with gypsum and anhydrite beds that are mined for industry. Other formations of the Salina Group are not known to be present west of Batavia, NY.

The Bertie Formation of the Upper Silurian age rests conformably on the Camillus Shale. The formation that is not exposed along the alignment has four members: the Oatka (oldest), the Falkirk, the Scajaquada, and the Williamsville. The Falkirk Member is the foundation rock of the Squaw Island Lock. The general characteristics of the members of the Bertie Formation as taken from the 1963 boreholes at Squaw Island are:

a. The Oatka Dolomite Member: light-brown to dark-gray, thin-bedded, argillaceous, shale beds, bands and parting throughout; gypsum parting, bands and nodules are found in certain beds; dense, soft- to moderately-hard, thickness approximately 23 feet.

b. The Falkirk Dolomite Member: light-brown to dark-gray, thin-bedded, very argillaceous dolomite and shale beds throughout, numerous gypsum partings, bands and nodules throughout, dense, soft to hard, thickness approximately 26 feet.

c. The Scajaquada Shale Member: bluish-gray to dark-gray and black, dolomitic, occasional calcite nodule, moderately-hard, thickness approximately 7.0 feet.

d. The Williamsville Dolomite Member: medium-gray, thin- to medium-bedded, several shale partings, very fine-crystalline, moderately-hard, thickness approximately 6 feet.

The Akron Dolomite is of the Upper Silurian System and rests conformably on the Bertie Formation. It is a thin- to medium-bedded, dense, moderately-hard, ruggy, greenish-gray to light-buff dolomite. Its thickness in the area varies from 1 to 8 feet.

The Onondaga Limestone rests unconformably on the Akron Dolomite. It is Middle Devonian and has three members in the area. These members are the Edgecliff Member, the Nedrow Member, and the Moorehouse Member. The Onondaga Limestone is generally thin- to massive-bedded, cherty, dense, moderately-hard to hard, and blue-gray in color. The total thickness of the formation is approximately 160 feet. The Akron Dolomite, Onondaga Limestone contact is south of the Squaw Island Lock near the sewage treatment plant.

B-13. Geologic Structure

The data on the rock structure are primarily from borings and from a few limited outcrops. There is no evidence of faulting or significant folding. The beds dip approximately 33 feet per mile in a southeasterly direction. The most significant structural features were found in the Queenston Shale. There is a fractured weathered zone at the top of rock. The Queenston also contains soft zones. Some joints and weathered zones were also found in the

overlying units.

The borings from the 1966-67 program in the Queenston Shale showed a fractured weathered zone that averaged 22 feet and ranged from 2.9 to 43 feet. The sound rock below had vertical joints up to 3 feet in length and at depths down to 150 feet from ground surface. Soft zones were also encountered in the sound rock and will be discussed in detail below.

In 1966 in borehole RC-66501, a 2.4 foot soft clay zone was found approximately 30 feet below the top of the rock. This zone consisted of angular fragments of shale in a clay matrix and is shown in Figure B4. Subsequent borings along the alignment uncovered numerous soft clay zones ranging in thickness from 0.4 feet to less than 0.05 feet. Examples of these zones are shown on Figure B5. A review of 20 borings either wholly or in part in the Queenston Shale was studied to ascertain the characteristics, position, and extent of any soft zone.

Five samples were sent to the Ohio River Division Laboratory for X-ray analysis of the soft material. The major constituents of the soft material consist essentially of quartz, illite, chlorite, kaolinite, feldspar, and hematite in decreasing order of abundance. The soft zones within the Queenston Shale are described as soft clay or plastic on the original field logs. In most cases, there are angular to subrounded shale grains in the matrix. While the size of the shale fragments varies according to the thickness of the

zone, they are totally absent in only a very few cases. In most of these clay zones, the fragments are aligned subparallel to the top and bottom of the zone.

While the majority of the zones were found within 30 to 40 feet of the top of rock, several were below 50 feet and some as deep as 100 feet (See Plates B20, B21, B22, B23). No firm correlations of the soft zones were found either along the bedding planes or subparallel to the top of rock line. This fact tends to imply that the zones are discontinuous over a distance that is not known at this time. The origin of the soft clay zones appears to be that of the shearing of the weak shale caused by the movement of the mountainous ice sheet during the glacial periods. This origin has been proposed for apparently comparable zones in different areas under similar glacial history by Knill (1968).

There were four borings drilled at the escarpment. The formations that were found in these borings ranged from the Queenston Shale to the Lockport Dolomite. Very few joints were found. Outcrops along the alignment were too poorly exposed to show the condition of the rock. Two roadcuts near the alignment were at Pekin, NY; one located at the lower escarpment exposed the Irondequoit Limestone to the Neahga Shale. The top few feet of Irondequoit were fractured and weathered. Some joints were found but only confined to particular beds. The Neahga Shale was weathered to clay. The second roadcut

in the upper escarpment exposed the Goat Island Member through the DeCew Member of the Lockport Formation. The beds showed some minor folding. The majority of the joints was in the beds of the upper Goat Island member in individual beds.

The bedrock of the Huron plain along the proposed waterway consists of the Lockport, Camillus, and Bertie Formations. Logs of the borings along the Huron plain showed a fractured zone in the upper 5 feet of the Lockport Dolomite and a few joints in the sound rock below. The boreholes at Squaw Island indicate a fractured weathered zone at the top of the Bertie Dolomite less than 15 feet thick. These boreholes also indicate a gentle dipping syncline just south of the proposed Black Rock Lock. This fold is shown on Plate B24.

B-14. Weathering in Bedrock

Weathering is the alteration of the rock during exposure to air, moisture, and organic matter by chemical and mechanical processes. Chemical weathering is the decomposition of rock, for example, solutioning of rock along joints and fractures. Mechanical weathering is the disintegration of rock, for example, rock fracturing due to wet-dry, freeze-thaw cycles. The two processes work in close coordination in the breaking down of sound rock. Uhl, Hall, and Rich, project engineers for the construction of the Robert Moses Power Plant

Niagara Falls, NY, conducted an experiment in 1959 on samples of shales that were exposed in the channel cut. The shale pieces were from the Queenston, Power Glen, Grimsby, Neahga, and Rochester Formations. The shales, along with a sample of gunnited Queenston Shale, were exposed to atmospheric condition for approximately three months. At the end of this period, all of the exposed shale disintegrated completely with the exception of a piece of dolomitic Rochester Shale that broke down into several pieces. The gunnited Queenston Shale did not appear to be be affected by atmospheric conditions. Figure B6 illustrates the results. These samples were obtained in bedrock less than 10 miles from the proposed waterway. The weathering of the bedrock along the proposed waterway is discussed according to its physiographic location.

The Queenston Shale of the Ontario Plain weathers rapidly into blocky chunks upon exposure to the atmospheric conditions by mechanical processes and eventually into clay. The information on the depths of the fractured and weathered zone to sound rock was taken from the 1966-67 boring program. The thickness of this zone along Alignment A-1 averages 22 feet and ranges from 2.9 to 43 feet.

As the rock formations of the escarpment vary lithologically, the weathering processes of those rocks differ also. The shales and some siltstones weather rapidly, by mechanical processes, into clay and silt to unknown depths into the face of the escarpment. The more

resistant sandstones, limestones, and dolomites may weather chemically and large voids along joints, fractures, and horizontal partings by ground water solutioning.

The bedrock of the Huron plain along the proposed waterway consists of the Lockport, Camillus,and Bertie Formations.

a. The Lockport Dolomite is resistant to weathering. Boreholes along the alignment indicate a weathered zone of less than 5 feet thick.

b. The Camillus Shale weathers readily by mechanical processes. The gypsum beds located in the formation are soluble in water and can be removed by solutioning. The fractured weathered zone found in boreholes along the alignment is approximately 15 feet thick.

c. The Bertie Dolomite, the foundation rock of the Squaw Island Lock, is fairly resistant to weathering. The Dolomite found in the boreholes at Squaw Island indicates a fractured weathered zone in the formation less than 15 feet thick.

B-15. Ground Water

The Lockport Dolomite and the Camillus Shale are the only two high-yield aquifers in the overland section. The Lockport Dolomite generally transports the ground water by artesian flow through open joint fractures and interconnected cavities. Water wells in the dolomite along the alignment yield ground water up to 110 gpm. These wells were drilled as far down as 50 feet into the rock.

Greater amounts of ground water are expected in the lower sections of the formation. In the Niagara Falls area, seven water bearing zones are found throughout the Lockport Dolomite (Johnston 1964). These zones and possibly more may be found in the waterway area. Regionally, the Camillus Shale is known to yield up to 1,200 gpm of ground water along solution cavities; however, there is no known ground-water information in this unit along the overland section of the waterway.

There is very little information on the ground water of the Silurian rocks below the Lockport Dolomite along the overland section. Generally, the Rochester Shale which underlies the Lockport Dolomite is impermeable. The sandstone and limestone formations of the Silurian strata that are good aquifers in some areas may, in fact, be poor due to the lack of recharge of the ground water. Water well data near the alignment indicate a very low-yield in these formations.

The Queenston Shale is a low-yielding aquifer. In the 1966-67 drilling program, the sound rock of this formation was pressure tested. The rock being tested was generally not capable of transporting water. Water wells drilled into the shale are generally seated in the fractured weather zone that is found at varying thicknesses above the sound rock. This zone yields up to 40 gpm of ground water in certain areas near the alignment although it generally yields less than 5 gpm.

The overburden of the overland section is generally a low-yielding aquifer. A few water wells are found in the Ontario plain along the alignment; however, they are only used for domestic purposes. In

contrast, the overburden of Squaw Island of the Niagara River section, which is made up of sands and gravels, is highly permeable. The ground-water table is approximately at the same level as the river. Water levels found in the borings along the alignment of the overland section and at Squaw Island are shown on Plates B11 through B19.

EXCAVATION

B-16. General

Excavation of overburden and rock will be required for all locks. Excavation of some overburden will be required for all dikes. In the canal cut from Lock 4-5 to the Niagara River, extensive removal of overburden and rock is necessary to produce the proper channel depth. Excavation for some of the guide walls will be necessary. Geologic profiles for the individual locks and its guide walls are shown on Plates B20, B21, B22, B23, and B24. Some of the excavated materials could be used for construction purposes.

B-17. Lock 1-5

The founding elevation for the lock walls is 175.0 feet (I.G.L.D., 1955) with a section for a conduit at an elevation of 168.0. The overburden that is generally glacial till and lacustrine silts and clays has a uniform thickness of approximately 25 feet. The bedrock of the lock area is the Queenston Shale. Approximately 90 feet of this rock is to be excavated. The average sound-rock line is at elevation 220. Excavation for the lower guide wall will be in overburden and rock to elevation 204.0. The removal of overburden to elevation 271.0

for the upper guide wall will be necessary. A preliminary estimate for the slope in the overburden cut generally will be 1V on 2H and for the shale cut 2V on 1H with berms to be provided where necessary for drainage and protection against spalling.

B-18. Lock 2-5

The founding elevation for the lock walls is 255.0. The conduit section will be as deep as elevation 245.5. The overburden, which has a thickness ranging from 30 feet on the downstream end to 60 feet on the upstream portion, is generally glacial till. Up to 40 feet of Queenston Shale must be excavated to reach the founding elevation. In the upstream end of the lock, from boring AUC-67516, the sound rock is estimated to be at elevation 242.8. This is 12.2 feet below founding elevation of the lock walls. The removal of overburden to elevation 286.7 for the lower guide wall will be required. No excavation other than stripping will be necessary for the upper guide wall. The overburden slope cut during excavation generally will vary from 2V on 5H to 1V on 5H, depending on height of cut. The cut in shale will be 4V on 1H, with a berm provided for drainage and protection against spalling.

B-19. Lock 3-5

The lock wall is founded on the Queenston Shale at elevation 328.0. The thickness of overburden varies from 10 to 20 feet and consists mainly of glacial till and sands and gravels of the ancient

beach of Lake Iroquois. The thickness of the bedrock to be excavated ranges from 30 to 35 feet. The sound-rock line is based on one hole and is at elevation 343.8. The removal of overburden for the lower guide wall to elevation 351.4 will be required. It is not necessary to excavate for the upper guide wall other than stripping. Temporary slopes during construction for the overburden cut generally will be 2V on 3H and for the rock cut generally will not exceed 2V on 1H with a berm provided for drainage and protection against spalling.

B-20. Lock 4-5

The founding elevation for the lock walls is 416.0. There were no boreholes at the actual lock site, and all data are extrapolated from boreholes along Alignment A. The overburden, which ranges from a few feet to approximately 40 feet in thickness, consists generally of glacial till. It is assumed that the lock will be founded on the Queenston Shale. Rock excavation from the upstream end of the lock probably will consist of shale, sandstone, and shaly sandstone from the Medina and Clinton Groups. The rock cut will have a 10V on 1H slope for sandstone and 2V on 1H for shale. The sound-rock line has not been determined at this site. No excavation for the lower guide wall is required. Rock excavation will be necessary in the Rochester and Irondequoit Formations to elevation 524.0 for the upper guide wall. The rock cut in the Irondequoit Limestone and the Rochester Shale will have a slope of 10V on 1H and 2V on 1H, respectively, with berms to be provided as required.

B-21. Overland Canal

The canal excavation from the end of the upper guide wall of Lock 4-5 to the beginning of the overland section at the Niagara River is to be excavated in both overburden and rock. The bottom of channel elevation is 531.0. The overburden consists generally of lacustrine silts and clays and glacial till and has a thickness varying from about 6 feet of till to about 50 feet of weak clay. The bedrock that will be excavated is from the Rochester, Lockport, and Camillus Formations. The thickness of bedrock to be excavated ranges up to 90 feet. The thickness of the overburden and rock excavation for the canal cut is shown on Plates B8 and B9. The slope of the channel cut in rock ranges from 10V on 1H in the Lockport Dolomite to 2V to 1H in the Rochester and Camillus Shale. The overburden slopes will generally vary according to depth and strength characteristics, however, for estimating purposes a 2V on 5H slopes were used, except where overburden cuts exceed 30 feet in depth and submergence was a factor. Overburden from Niagara River to approximately Station 1290+00 varies from about 30 to 50 feet of weak clay. Some excavation in the Camillus Shale can be expected. Between Sta. 1290+00 and Sta. 1420+00, there is a maximum of about 90 feet of Lockport Dolomite to be excavated along with a shallow mantle of overburden, mainly till.

B-22. Lock 5-5

The founding elevation for the lock walls is 510. The center line of the original lock site, which has six borings drilled into

rock, has been relocated about 200 feet toward the river. The rock depth and condition at the lock site can only be extrapolated from these boreholes. The overburden is a sand and gravel material that ranges from 45 to 65 feet. Considerable fill from the nearby garbage disposal plant is present. The bedrock is Bertie Dolomite and its excavation is assumed to be up to 12 feet. The sound-rock line based on one borehole outside the lock area is at elevation 514.1. Overburden removal is expected for the upper and lower guide walls. The slopes in the overburden for excavation will be determined from actual boring data and will depend on seepage and uplift pressures and other factors affecting the stability. However, for this report it is assumed that the overburden cut will be 1V on 1.5H.

B-23. Existing Canal

Deepening of the existing Black Rock Canal will be required. Upstream of the existing Black Rock Lock the required channel depth will be at El.539. Downstream of the lock the required channel depth will be at El.534. Rock excavation will be required both upstream and downstream of the lock. Upstream of Squaw Island the rock to be removed is Onondaga limestone. Downstream the rock to be removed consists of Camillus Shale. The overburden to be removed varies from silty sand to glacial till.

FOUNDATION CONDITIONS

B-24. Locks 1-5, 2-5, 3-5

The foundation conditions for Locks 1-5, 2-5, and 3-5 are

similar. The overburden for the three locks is generally glacial till with some lacustrine clays and silts. However, sand and gravel materials of the beach ridge are found on the upstream portion of Lock 3-5.

The three locks are founded on the Queenston Shale. This formation as discussed previously in Section B-13, Geologic Structures, has discontinuous soft clay zones of varying thicknesses above and below the founding elevations of the lock walls to an approximate depth of 100 feet into rock. A thickness of 10 feet of sound Queenston Shale was determined to sufficiently reduce stresses in soft zones to prevent differential settlement and plastic flow. There were no soft zones found below the founding elevations in the borings of Lock 1-5 (Pl B20). In Lock 2-5, a minimum thickness of 10.6 feet of the lock walls and the soft zones was found in borehole C-67516 (Pl B21). In Lock 3-5, a minimum thickness of 17 feet of sound rock between the founding elevation of the lock walls and the soft zones was found in borehole ARC-66508 (Pl B22). The occurrence of soft zones will require additional explorations and analysis in subsequent studies.

A weathered fractured zone located at the top of rock was found in all boreholes. The founding elevations for all of the lock walls are below this zone. Joints found in boreholes were usually tight and vertical. Ground-water seepage during construction

may occur along the weathered fractured zone in the shale and along the beach ridge in the overburden; however, it is not expected to produce any major problems. The shale,which weathers readily upon exposure to atmospheric conditions,should be protected during construction. A major grouting program for the bedrock is not expected.

B-25. Canal Dikes

The reaches of the canal dikes from Lock 1-5 to Lock 3-5 has generally the same geologic conditions. The overburden is generally a firm glacial till with lacustrine clays and silts in some areas. The rock underlying the overburden is the Queenston Shale. The canal dikes from Lock 1-5 to Lock 2-5 have a crest elevation of 331.7 and are approximately 9,000 feet long. The dikes from Lock 2-5 to Lock 3-5 have a crest elevation of 411.4 and are 12,000 feet long. Due to the length of the dikes, differential settlement may occur along these reaches.

The canal dikes from Lock 3-5 to Lock 4-5 are approximately 2,000 feet long and have a crest elevation of 491.1. The overburden of the area is made up of a sequence of clays and silts overlying semi-pervious to pervious sand and gravel material. The overburden thickness varies from 60 feet to approximately 120 feet. The sands and gravels are in a buried depression that runs along the escarpment. The bedrock is Queenston Shale.

B-26. Lock 4-5

The closest borehole to the lock site is 1,500 feet to the east.

By extrapolation, it is anticipated that the Queenston Shale will be the foundation bedrock for the lock walls. The Medina and Clinton Group will be exposed on the upstream end of the lock. Ground-water seepage can be expected and grouting should be considered.

B-27. Overland Canal

The canal cut from Lock 4-5 to the Niagara River will be in overburden and rock. The overburden for the northern half of the canal cut is firm glacial till and for the southern half is weak lacustrine clay and silt underlain by glacial till. The rock that will be excavated will be the Rochester, Lockport, and Camillus Formations. Stresses in the Rochester Shale and Lockport Dolomite may produce a convergence when the cut is made and should be considered in the design of bridges crossing the canal. The Lockport Dolomite and Camillus Shale are high-yielding aquifers, and seepage can be expected during construction.

B-28. Lock 5-5

Lock 5-5 is located partly on Squaw Island and partly in the Niagara River. The overburden of Squaw Island where the lock will be located is highly pervious. The foundation rock of the lock is the Bertie Dolomite and is fractured to a depth of 15 feet from top of rock. Seepage can be expected to be a major problem during construction. Grouting can be expected.

DESIGN CONSTANTS

B-29. Rock

On the basis of tests performed by NCD and ORD on the Queenston Shale, the following preliminary constants for this intact material were established:

Internal Friction	Tan Ø = 0.700
Compressive Strength (Allowable)	33 tons per sq. ft. Maximum
Modulus of Elasticity, "E"	390,000 pounds psi
Unit Weight	165 pounds per cubic foot
Resistance to Sliding	Tan Ø - 0.30

Initially placed, this Queenston Shale and other similar excavated shales were assumed to have the same characteristics as the dolomitic limestone to be used in the dike shell, as follows:

Angle of Internal Friction	Ø = 40 degrees
Cohesion	c = 0 psf
Unit Dry Weight (based on 30 percent voids)	w = 115.5 pcf
Submerged Unit Weight	W_{sub} = 72.0 pcf

A substantial amount of excavated shale will be used in toe berms on the dike sections. Most of this material weathers readily into blocky chunks when exposed to the atmosphere (refer to the Local Geology section of this report, paragraph B-12) and in most instances (over a prolonged period of time) would revert to a semigranualar soil mass of its component minerals - illite, chlorite, kaolinite, and montmorillonite with some quartz, and eventually into clay.

In view of the foregoing, the following conservative preliminary design values were assigned this material for the possible ultimate

weathered condition in compacted toe load berm fills:

Angle of Internal Friction	ϕ = 10 degrees
Cohesion	c = 200 psf
Unit Dry Weight	w = 115.5 pcf
Submerged Unit Weight	W_{sub} = 72.0 pcf

B-30. Overburden

From comparison of test data with blow counts, there are apparently five zones in the overburden from the Niagara Escarpment north to Lake Ontario. These zones vary considerably in thickness, and definitive drilling programs will be required to establish their extent, reach by reach.

Preliminary design constants for these zones were established by evaluating the constants determined for the in situ soils and assessing the amount of strength increase expected due to consolidation of these soils under the weight of the dikes during construction. The design constants so determined are considered to be realistic and conservative, but will require verification by appropriate test programs conducted in conjunction with final design studies.

The preliminary design constants established for the previously mentioned zones are as follows:

Zone No.	Zone Designation	Cohesion "C" in Psf	Unit Dry Weight Pcf	Moisture Percent of Dry Wgt.
I	Upper Clay	1,500	113,3	18.2
II	Intermediate Clay	1,000	103.8	23.5
III	Middle Weak Clay	900	89.8	33.4
IV	Lower Clay	1,500	113.3	18.2
V	Till (Presumptive Values) c = 1,000 ϕ = 25 degrees		135.0	10.0

The submerged unit weight required in the analyses performed was calculated using the foregoing values, and the specific gravity and void ratio values determined by test are shown in Table B3.

Upstream of the escarpment, from about Lockport Road to the Niagara River, the overburden changes from the thin till mantle to clay. This clay extends to 50 feet in places, and indications from Borings RUDC 28 and 29 are that it is quite weak. The preliminary design constants for this clay in situ are:

C = 125 pounds per square foot
Unit dry weight = 85 pounds per cubic foot
w = 35 percent (of the unit dry weight)

Much of this material will be utilized as core material in the impervious dikes. Obviously, considerable processing, particularly aeration to remove excess moisture, will be required to achieve the density and impermeability required in the core. It is presumed that the compacted material will have properties comparable to the best underlying soils in the major dike areas, thus the following constants were established for the clay core:

(PRESUMPTIVE VALUES)

Compacted Clay Core Material*	Cohesion C in Psf	Unit Dry Wgt. Pcf	Moisture Percent of Dry Wgt.
As Placed	1,500	105	19.0
Saturated	1,000	105	23.4

*Angle of Internal Friction Ø = 0 in all cases.

CONSTRUCTION MATERIALS

B-31. Rock

The amount of rock that will be excavated during the construction of the waterway is approximately 37,113,000 cubic yards in situ. The estimated quantities of each type of material to be excavated are summarized in Table A4 in Appendix A.

Calculations indicate that sufficient durable Lockport Dolomite will be obtained from the channel cut to satisfy the requirements for riprap, rock-fill breakwater material, and coarse and manufactured fine aggregate for concrete and bedding and filter materials. During the construction of the Robert Moses Power Plant the Lockport Dolomite, with the exception of the DeCew member, was used for the coarse and fine aggregates for concrete. The stone proved excellent quality for both aggregates. The Lockport Dolomite at the waterway site is less than 10 miles east of the power plant, and its quality is assumed comparable. Other rock types, notably Camillus Shale, will be utilized for construction materials in toe load berms for dikes at many locations (refer to Table B4 which lists the rock formations that will be excavated and their possible uses).

B-32. Overburden

The amount of overburden soil excavated during construction of the waterway will be approximately 37,960,000 cubic yards in situ. The amount of clay core material required for the impervious dikes is

calculated to be 4,787,000 cubic yards and will be selected from the most impermeable overburden soils available in the excavation areas of the waterway. Available soil boring and laboratory test data indicate most of the clay core material will be selected from deposits upstream of the escarpment from about Lockport Road to the Niagara River.

The borings taken to date indicate some superficial silty and clayey sand and gravel deposits exist in dike areas that will probably require excavation, as will those deposits occurring in the general excavation areas. These materials and all others that have soils constants comparable or superior to those values assigned disintegrated shale can be used in dike toe berms in noncritical areas, as shown in Plates A7 through A10.

The use and disposition of all excavated materials is covered more fully in Appendix A under Use and Disposal of Excavated Materials.

DIKE DESIGN

B-33. Design Procedure

The procedures followed in the investigation of the stability of dikes and dike foundations and their effectiveness against seepage losses were as follows:

a. Since many typical sections as originally conceived were quite similar, groups of such sections were determined, and typical

sections in each group were selected for analysis. In each case the most critical section was used; i.e., for a given configuration the highest dike section founded on the deepest typical subsoil formation was chosen for evaluation.

b. All necessary computations were performed to determine additional basic data required in the analyses, such as wet density and submerged unit weights, using the preliminary design constants previously presented and the test data in Table B3.

c. Stability analyses were performed, using the Swedish slip circle method of analysis, on the typical sections, mentioned previously.

Sections found to be unstable were redesigned as required to meet acceptable factor of safety requirements.

d. Seepage analyses flow nets were prepared for typical high and low sections on rock, a typical high dike section over a thick and a thin foundation section, and a typical low dike over a thick and a thin foundation section. Average horizontal and vertical permeability factors were determined from the test data in Table B3, and these values were used for both the foundation and core. In the case of the core, it was considered very conservative to apply the same factors, since a substantial increase in permeability factors will be realized in the compacted state.

B-34. <u>Stability Analysis</u>

Most of the sections as originally conceived were found to be

unstable due to excessive dike height on weak foundation soils, when evaluated against the minimum factors of safety set forth in EM 1110-2-1902 Engineering and Design Stability of Earth and Rock Fill Dams. In these cases, the sections were redesigned to meet the required criteria using the slip circle method of analysis.

Two types of revised sections were considered, flattening slopes and adding toe load berms to the existing sections. The toe load berm method was determined the more economical means of achieving the desired results, hence this design revision method was standardized throughout.

Stability analyses were performed for various toe load berm heights on the typical sections to establish top of berm elevations required for the highest section in each (lock to lock) reach of the canal. The top of berm elevation so determined for each reach was held constant throughout that reach for practical and aesthetic reasons; thus, the safety factors for the bulk of the dikes are higher than those established for the basic critical sections.

The three basic design conditions having the most severe safety factor requirements were used in the analysis of the typical sections. These conditions and the minimum factor of safety required in each use are as follows:

End of Construction	1.4
Partial Pool with Steady Seepage	1.5
Steady Seepage with Maximum Storage Pool	1.5

These cases were evaluated for upstream and downstream slopes as appropriate. Since all other design conditions have less stringent factors of safety requirements, spot checks on selected sections for these conditions were made that verified the revised designs to be satisfactory.

Additional stability analyses were performed on the revised design sections to determine the suitability of using shale or other degradable materials with comparable physical characteristics in the toe load berms at selected locations. The locations of permissible use for these materials are designated on Plates A7 through A10.

The stability analyses were performed with the aid of an electronic computer. The locations of trial failure arcs were set manually by an experienced soils engineer to assure that the critical circle location was not influenced by the limitations of a programmed search procedure.

The location of the failure planes, used in stability analyses checks performed by the sliding wedge method of analysis, were also set manually by an experienced soils engineer. Therefore, the computer program used in this analysis also served the sole function of reducing computational effort.

B-35. Seepage Analysis

All of the seepage analyses performed were based upon average

horizontal and vertical permeability factors presented in Table B3. Ten sets of horizontal and vertical permeability factors determined by tests on undisturbed specimens are available. Of these 20 tests, three were obvious outliers, that is, nontypical insofar as the other 17 are concerned, and were not included in the averages. The legitimacy of these tests is not in question. However, it was felt they represented localized deposits of more permeable material that will have to be treated as separate problems when encountered during construction (refer to the Conclusions and Recommendations section which follows for a discussion of this item). The average in situ foundation soil permeability factors used in the analyses were as follows:

Vertical Permeability Factor $K_v = 183 \times 10^{-9}$ cm/sec

Horizontal Permeability Factor $K_h = 310 \times 10^{-9}$ cm/sec

These same factors were also used for the compacted dry core material, which is considered to be a conservative approximation.

To facilitate making rational seepage estimates for the various combinations of dike heights and foundation soil thickness encountered throughout the overland section, flow nets were constructed for the following general conditions:

	High Core	Low Core
Head of Water, Feet	96	26
Foundation Soil Thickness, Feet	0	0
Foundation Soil Thickness, Feet	20	12
Foundation Soil Thickness, Feet	40	25

Transformed sections were constructed, and seepage quantities per linear foot of dike were calculated for each of the above combinations.

The total computed seepage loss for the overland section of the canal, through and under the dikes, is 6,550 cubic feet per day. This is very low and reflects the relatively low permeability factors. Obviously, detailed exploration will reveal areas of much higher subsoil permeability that exist in localized locations, as indicated by the three tests deleted from the permeability factor averages. These areas when encountered will require specialized corrective action, such as excavation and replacement, extended cores, or cutoff walls.

The total computed seepage loss through and under the Niagara River section dikes is a nominal 150 cubic feet per day. However, this quantity is considered inconsequential compared to the uncertainties of inflow or outflow of groundwater in the cut sections of the canal. Reference is made to paragraph B-7 of this Appendix that indicates the Lockport Dolomite has water flowing through fractures, joints, and open bedding planes that yields as much as 100 gallons per minute (19,250 cubic feet per day), and flow through the Camillus Shale of as much as 1,200 gallons per minute (231,000 cubic feet per day). Hence, it appears highly probable that water inflow will be a far more significant factor in this section than will seepage losses through the dike.

SUMMARY AND CONCLUSIONS

B-36. General

As stated in the opening paragraphs, the purpose of this appendix is to describe the geologic conditions and the effect of these conditions on the canal and lock areas of the proposed waterway. Those geologic conditions have been described in considerable detail in the preceding sections of this appendix.

The objective of this final section is to summarize the salient points made and to assess their probable effects upon the design and construction of the proposed waterway.

As noted in the introduction, this appendix stressed the following:

Characteristics of the Overburden and Bedrock
Geologic and Soil Investigations and Tests
Foundation Conditions at Lock Sites
Sources of Construction Materials

The conclusions and recommendations which follow also concentrate on these items and their significance to the project.

B-37. Overburden

Substantially more geologic data are available relative to the rock formations and their characteristics than is available on overburden soils for the immediate waterway area.

Realignment of the canal after initial soils exploratory work

was performed has resulted in some of the borings being too far removed from the present line to be reliable for design purpose.

Although a substantial amount of exploratory work has been performed to date, detailed subsurface profiles beneath actual dike locations, along with substantially more laboratory test data, are required to verify the preliminary dike designs established in this study.

The overburden of the Ontario plain along the proposed waterway is generally glacial till that blankets the Queenston Shale and consists of a clay silt matrix with some sands, gravels, and boulders. The overburden thickness of the Ontario plain along the alignment averages 30 feet and ranges from 10 feet to 120 feet. These variations in thickness of overburden could be a source of significant differential settlements in dikes and guide walls and will have to be investigated further. The physical characteristics of these soil deposits have been listed in paragraph B-30, and the strata thicknesses used in the analyses were established from generalizations of the applicable soil boring test data presented in Table B-3 and the various Profiles B-8 through B-19.

The overburden of the Huron plain along the overland section is composed of glacial till and lacustrine deposits. Till covers most of this plain and generally has the same characteristics as the till of the Ontario plain.

Extensive deposits of lacustrine silts and clays overlie the till along the alignment from four miles south of the escarpment to the Niagara River. The thickness of the overburden averages 23 feet and ranges from 3 feet to 50 feet.

Selectivity of the overburden soils to be excavated in the overland section will provide all the core material required for the dikes. The remainder of the excavated soils will be disposed of as detailed in Appendix A.

Further exploration of the overburden soils in this area will be required to locate the most suitable core material and to further explore the cut stability characteristics of these in situ soils at the slopes set in this preliminary study.

The overburden of the Huron plain at Squaw Island has an average thickness of 65 feet. North of the International Bridge, the overburden is sands and gravels ranging in thickness from 45 to 65 feet. South of the bridge, the material consists of fill underlain by silty clay and is 60 to 90 feet thick.

Lock 5-5, located partly on Squaw Island and partly in the river, will be in the pervious sand and gravel area, and seepage will be a major problem during construction.

Excavation of some overburden will be required for all dikes. However, in most instances only topsoil stripping will be required

unless soft, unstable, underlying soil or highly pervious deposits are encountered.

B-38. Rock

Virtually all the overland cut section will be in rock. Evidence of convergence and uplift in the Lockport and Rochester formations indicates that horizontal and vertical active stresses are present in the rock and will present problems that must be considered.

In Lockport, NY, at the bottom of the Barge Canal, the Rochester Shale is rising, and it is necessary to remove rock every year in order to maintain the proper depth of the canal.

Numerous other examples of rock displacement as a result of load release due to excavation indicate that this is not an isolated phenomenon,and it must be considered in setting depths of cut through these formations in the final design stage.

The suitability and possible uses of excavated rock types are presented in Table B4.

In general, the best rock will be utilized in the most critical components of the structures and dikes, with the less desirable stone utilized in less critical areas.

B-39. Foundation Conditions

The foundation conditions for Locks 1-5, 2-5, and 3-5 are

similar. The overburden for the three locks is generally glacial till with some lacustrine clays and silts, with the exception of sand and gravel materials of the beach ridge found on the upstream portion of Lock 3-5. All three locks are founded on Queenston Shale. The presence of soft clay zones of varying thicknesses above and below the various founding elevations of these structures was studied in considerable detail. At this point, it is believable that these clay zones are predominantly very thin and discontinuous. A thickness of 10 feet of sound Queenston Shale overlying one of these zones was determined sufficient to reduce stresses in the zone to prevent differential settlement and plastic flow. However, frequency of occurrence of these soft zones will require additional explorations and analysis in subsequent studies.

A weathered fractured zone at the top of rock was found in all boreholes. However, since the founding elevations of all locks and lock walls are below this zone, few problems of consequence (other than seepage during construction) are expected.

Insofar as the foundation of the dikes within the reaches of the first three locks are concerned, some differential settlement may occur due to length of the dikes and the variability of subsoil characteristics and thickness beneath the dike. Additional exploration and testing will be required to facilitate estimation of the amount and variability of this settlement.

The canal dike foundation soils between Lock 3-5 and Lock 4-5 will also require additional exploration and testing to assess the implications of excessive overburden thicknesses within this reach and possible permeability problems associated with the underlying sand and gravel deposits in the buried depression along the base of the escarpment.

It is anticipated that the Queenston Shale will be the foundation bedrock for Lockwalls 4-5, and since the Medina and Clinton Group Limestone rock will be exposed on the upstream end of Lock 4-5, ground-water seepage can be expected, which may require grouting.

Foundation soils in the northern half of the Niagara River section starting above Lock 4-5 are firm glacial till. However, the southern half is weak lacustrine clay and silt (underlain by glacial till) that will present settlement and stability problems for any structures founded on these weak soils.

Further subsoil boring and testing will be required in this area at specific structure locations to facilitate proper final design of cut and dike slopes.

Lock 5-5 will be founded on Bertie Dolomite, which is fractured to a depth of as much as 15 feet below the top of rock. Seepage in this area will be a major problem during construction of the structure and grouting will probably be necessary.

B-40. Construction Materials

A favorable balance between materials available from the cuts in overland section and the dike and structure needs of the overland section was discovered. Thus, it is not anticipated that any borrow or disposal areas outside of the canal right-of-way will be required.

Sufficient Lockport Dolomite is available to provide all fine and coarse aggregate for the concrete required in all the structures, plus riprap, breakwater material, and the shells for the dikes including the toe load berms at critical locations.

Since there will be a surplus of shale excavated, most of this material will be used for toe load berms, particularly exterior berms that will not be submerged, and for interior berms at less critical locations.

The preliminary plan for use and disposition of all excavated materials, including calculated quantities, is presented in Appendix A.

As will be noted, excess material disposition will be made within the canal and surge basin limits of the overland section. It is anticipated that the locations currently indicated will be varied to more effectively increase dike toe loads to achieve greater stability where final design may indicate such needs exist.

B-41. Design Considerations

In the preliminary dike designs established herein, every

effort was made to use realistic data and rational design procedures. Final designs based on more complete data will certainly result in additions and modifications, involving such things as toe load berm height adjustments, toe berm slope adjustments (or reinforcement with limestone when shale is used), and determination of section details, such as intermediate filter layers between the clay core and shell rock. Many of these items are beyond the scope of this study. However, certain design considerations that must be resolved in future studies merit discussion.

The dike design investigation conducted for this report established a basically sound configuration well-suited to the predominant subsoil conditions. However, since it was necessary to base designs upon generalized subsurface soils profiles, additional studies must be made, based on specific data for each reach of the waterway. Such additional studies can be expected to reveal areas where added toe load berm heights will be required, areas where additional excavation of soft and unsuitable soils will be required, deposits of porous material that will require extension of the clay core into the underlying strata, bottom areas that will require blankets of impermeable material, and areas of high settlement potential that may require sand drains, etc.

Such problem areas, expected to be the exception not the rule, accentuate the need for additional comprehensive soils investigation.

As mentioned previously, blankets of intermediate size material will be required on both sides of the clay core to prevent migration of this clay into the porous shell rock. It is anticipated that this material can be manufactured from the Lockport Dolomite, as will the concrete aggregates.

It should be noted that where shale or any other degradable rock or fine grained soil is used for toe load berms on the dike exterior, such material must be underlain by a drain blanket of porous material to prevent a head buildup in the outer shell of the dike.

Further study of the physical characteristics inherent to degraded shale and other similar materials that may be used in toe load berms should be made to facilitate final design utilization of these materials. In general, extensive use of deteriorating material in critical dike toe areas, particularly on the upstream side of high dike sections, should be carefully analyzed.

The Erie-Ontario lowland is in the seismic Zone 3 area, where major destructive earthquakes may occur. The shallow excavation for the overburden canal would have no appreciable effect on the occurrence of seismic disturbance. The design of the structures of the waterway should take into account the earthquake factor.

Insofar as the dikes are concerned, design checks indicate

safety factors in excess of the required FS = 1.0 for earthquake design conditions (Case No. 7, EM 1110-2-1902).

Preliminary stability design checks utilizing the sliding wedge method were made to assess possible consequences of thin continuous strata of weak material in the subsoils. Indications are that such conditions underlying dike fills will be critical, and the possible existence of such conditions, particularly at guide wall locations, must be thoroughly investigated.

Based on the studies and analyses performed, it is concluded that construction of the proposed waterway is feasible insofar as local soils and geologic conditions are concerned. This conclusion presupposes that the available data are typical for the site as a whole and that the conditions assumed in the analysis are valid.

It is also concluded that the preliminary designs are realistic for the site and will result in maximum utilization of on-site materials with no excessive borrow or waste required.

It is further concluded that numerous localized design and construction problems will be encountered, but that these problems can be anticipated and resolved to a great extent by further field and laboratory investigations of the various in situ materials throughout the site.

Table B1 Compilation of earthquakes of western New York and vicinity

DATE	EPICENTER DATA INTENSITY (MODIFIED MERCALLI)	N. LAT. (DEG.)	W. LONG. (DEG.)	LOCALITY	AREA AFFECTED (SQ. MI.)	AUTHORITY
1969 August 12	IV	42.8	78.2	Attica	--	NOAA
1967 June 13	V	42.8	78.2	Attica	--	Canisius College & Dominion Observatory, Ottawa
1966 Jan 1	VI	42.8	78.2	Attica	3,500	ESSA
1965 Aug 29	IV	--	--	Attica	--	ESSA
1965 July 16	IV	--	--	Attica	--	ESSA
1962 Mar 27	V	--	--	Niagara Falls	--	Canisius College
1958 July 21	IV	--	--	St. Catherines, Ont	--	Canisius College
1955 Aug 16	V	42.5	78.3	Attica	--	ESSA
1946 Sept 20	IV	--	--	Niagara Falls	--	Canisius College
1939 June 13	II	--	--	Niagara Falls	--	Canisius College
1939 Mar 23	II	--	--	Niagara Falls	--	Canisius College
1929 Aug 12	VIII	42.9	78.3	Attica	100,000	ESSA
1879 Aug 21	V	43.2	79.2	Canada near Bflo.	1,300	ESSA
1873 July 6	V	43.0	79.5	W. of Niagara Falls, in Ont.	30,000	ESSA
1857 Oct 23	VI	43.2	78.6	W. New York	18,000	ESSA

Table B2 Borehole data. Locations of boreholes taken along centerline of canal using Alignment A-1. All holes are vertical.

Boring No.	Location Sta-Rg	Surf. Elev.	Depth of Overb. (ft)	Depth in Rock (ft)	Total Depth (ft)	Size core	Date Drilling comp.
			Drillholes Prior to 1966				
RDC-1	1964+00-14,240RT	270.2	26.6	50.2	76.8	NX	1/15/63
RDC-4	1909+50-12,000RT	295.2	38.0	52.1	90.1	NX	1/26/63
DC-5	1896+10-11,480RT	293.7	26.5	68.3	94.8	NX	2/5/63
UDC-5A	1897+40-11,520RT	296.2	27.0	101.1	128.1	6"	3/16/63
RDC-6	1884+00-11,240RT	299.3	54.6	51.0	105.6	NX	2/14/63
RUDC-16	1612+00-2,600RT	381.8	57.0	25.0	82.0	NX	12/4/64
RDC-16A	1603+10-2,300RT	384.1	59.0	25.0	84.0	NX	12/7/64
RDC-16B	1596+70-1,600RT	389.7	64.0	25.0	89.0	NX	1/25/65
RDC-17	1588+00-1,300RT	394.2	79.0	25.0	104.0	NX	1/6/65
RDC-17A	1579+00-1,150RT	394.7	98.0	25.0	123.0	NX	12/17/64
RUDC-17B	1575+00-1,000RT	398.7	102.0	25.0	127.0	NX	12/18/64
RDC-18	1569+50-775RT	408.3	124.6	51.6	176.2	NX	3/29/65
DC-19	1563+00-550RT	444.1	2.6	70.1	72.7	NX	4/4/63
DC-20	1553+50-700RT	502.2	38.3	54.8	93.1	NX	3/15/63
RC-21	1541+50-880RT	542.5	2.4	145.2	147.6	6"	4/11/63
RC-22	1505+50-1,480RT	566.8	48.6	93.0	141.6	6"	3/28/63
RDC-23	1500+00-1,640RT	623.0	7.5	115.5	123.0	NX	1/28/65
RC-24	1456+00-2,080RT	644.1	7.6	53.8	61.4	6"	4/15/63
RC-24A	1455+92-2,080RT	644.1	3.0	209.9	212.9	6"	4/24/63
RDC-25	1413+80-2,780RT	651.4	5.0	146.5	151.5	NX	1/21/65
RDC-26	1377+00-2,100RT	633.5	10.0	124.0	134.0	NX	2/11/65
DC-27	1328+00-1,100RT	620.7	6.5	94.0	100.5	NX	4/22/65
RUDC-28	1223+00-100LT	574.9	25.0	35.0	60.0	NX	2/16/65
RUDC-29	1105+08-69,500RT	571.9	25.8	18.9	44.7	6"	2/17/65
SI-DC-1	534+78-39RT	569.1	45.1	50.4	95.5	NX	2/12/63
SI-DC-2	525+78-88RT	569.3	49.8	50.6	100.4	NX	2/18/63
SI-DC-2A	527+70-60RT	569.7	49.5	40.5	90.0	6"	4/4/63
SI-DC-3	517+00-143RT	590.1	78.4	50.7	129.1	NX	2/27/63
SI-DC-4	502+85-80RT	590.0	91.3	25.6	116.9	NX	3/13/63
SI-DC-5	493+78-58RT	579.9	63.3	25.5	88.8	NX	3/6/63

Table B2 Borehole data. Locations of boreholes taken along centerline of canal using Alignment A-1. All holes are vertical.

Boring No.	Location Sta-Rg	Surf. Elev.	Depth of Overb. (ft)	Depth in Rock (ft)	Total Depth (ft)	Size core	Drilling comp.
			Drillholes 1966 - 67 Program				
RC-66501	1958+25-810LT	258.6	17.7	137.1	154.8	6"	7/25/66
U-66502	1621+50-1,400RT	389.5	40.0	-	40.0		7/26/66
RC-66503	1941+00-780LT	272.6	28.5	102.8	131.3	NX	11/1/66
RC-66504	1912+00-190LT	297.4	27.3	123.0	150.3	NX	10/27/66
RC-66505	1836+75-780LT	306.6	29.4	131.0	160.4	NX	11/8/66
RC-66507	1647+00-900LT	364.6	15.8	134.3	150.1	NX	11/23/66
ARC-66508	1622+50-575LT	388.1	32.9	102.2	135.1	NX	12/1/66
ARC-66509	1784+50-200LT	313.8	48.0	83.7	131.7	NX	11/14/66
ARC-66510	1807+90-675LT	312.4	19.5	111.0	130.5	NX	11/18/66
AUC-67511	1692+00-800LT	331.7	22.0	96.0	118.0	NX	10/25/67
ADC-67512	1638+75-475LT	367.7	7.5	103.6	111.1	6"	11/6/67
ADC-67513	1656+50-275LT	350.9	7.5	98.5	106.0	NX	11/9/67
DC-67514	1827+75-430LT	307.4	28.5	94.2	122.7	NX	11/16/67
AUDC-67515	1953+00-280LT	265.9	25.0	99.7	124.7	NX	11/23/67
AUC-67516	1798+00-425LT	313.3	46.6	79.8	126.4	6"	11/29/67

Table B4 Possible uses of excavated rock

Rock Type	Thickness	Location of Excavation	Possible Use	Service Record	
Lockport Dolomite Oak Orchard Mem Eramosa Mem Goat Island Mem Gasport Mem	+128'	Station 1170+00 to 1505+00	Coarse and manufactured fine aggregate for concrete bedding, filter material, riprap, breakwater material, dike fill	P.A.S.N.Y. Robert Moses Power Plant many quarries in this formation are approved by Corps of Engrs for concrete aggregate and riprap	Selective quarrying required for concrete aggregates, riprap
Lockport Dolomite DeCew Mem	10'	Station 1400+00 to 1505+00	Dike material, channel fill and waste		Selective placement in channel
Clinton Group	90'	Station 1415+00 to 1545+00	Breakwater material (Irondequoit Limestone) Dike material, channel fill and waste		Selective quarrying in the Irondequoit Limestone Selective placement in channel
Medina Group	122'	Lock 4-5	Breakwater material (Thorold and Whirlpool Sandstone) Dike material, channel fill and waste		Selective quarrying in the Thorold and Whirlpool Sandstone Selective placement in channel
Queenston Shale	+1,200'	Lock 1-5, 2-5, 3-5	Breakwater material channel fill and waste		Selective placement in channel
Camillus Shale	+400'	Station 1160+00 to 1170+00	Dike material, channel fill and waste		Selective placement in channel
Bertie Limestone	65'	Lock 5-5	Waste		
Onondaga Limestone	160'	Station	Breakwater material, Dike material	Quarries in this formation are approved by Corps of Engrs for concrete aggregate & riprap	Selective placement in breakwater & dike

TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION ... WATER %	MAX DRY ...
UDC-5A	3	38.6	QUEENSTON SHALE							2.78	1.9	162.1		
EL. 292.6														
TOP OF	6	41.5	QUEENSTON SHALE							2.76	2.0	158.0		
HOLE														
	9	53.0	QUEENSTON SHALE							2.72	1.8	161.7		
	10	71.2	QUEENSTON SHALE							2.81	1.8	161.2		
UDC-5A	10	71.2	QUEENSTON SHALE							2.81	1.8	163.0		

ENG FORM 1 MAR 58 2086 (PREVIOUS EDITIONS MAY BE USED)

ABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

URAL ENSITY CU FT	COMPACTION DATA: OPT WATER %	COMPACTION DATA: MAXIMUM DRY DENSITY LBS CU FT	SHEAR DATA: INITIAL e	DRY DENSITY LBS CU FT	w_I %	w_F %	S_I %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T SQ FT	σ_I T SQ FT	C T SQ FT	ϕ DEGREES	PERM: e
.1															
.0															
.7															
.2															
.0															

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Undrained
CD –
CU –

					PERMEABILITY		CONSOLIDATION DATA				
	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	e	K_{20} FT MIN $\times 10^{-9}$	P_o T SQ FT	P_c T SQ FT	C_c	t_{50} *	REMARKS
							2.7	1.2	.0025		JUNE 1961 BY NCD
							2.95	6.8	.0015		
							3.9	0.95	.0025		
							5.4	2.6	.0024		
							5.4	1.0	.001		

DS – Direct Shear
UU – Unconsolidate Undrained
CD – Consolidated Drained
CU – Consolidated Undrained
* Values at Pressure T/SQ FT

TABLE B3

BORING NO.	SAM NO	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION OPT WATER %	MAX DRY D LBS/
RUDC-16	1	380.3-378.8	ORGANIC CLAY (OH)					72.3	37.3		66.8	54.7		
	2	378.8-377.3	ORGANIC CLAY (OH)					69.6	35.2	2.55				
	3	-375.8	CLAY (CL)					34.6	17.7	2.76				
	4	-374.3	CLAY (CL)					32.9	15.9	2.75				
	5	-372.8	CLAY (CL)							2.77	18.1	114.3		
								34.6	17.7	2.77	17.9	114.4		
								34.6	17.7	2.77				
	6	-371.3	CLAY (CL)					34.3	17.1	2.77				
	7	-369.8	CLAY (CL)					-	-	2.78				
	8	-368.3	CLAY (CL)					32.4	16.7	2.77				
	9	-366.8	CLAY (CL)					34.8	15.4	2.78				
	10	-365.3	CLAY (CL)					32.8	16.9	2.78				
	11	-363.8	CLAY (CL)					-	-	2.77				
	12	-362.3	CLAY (CL)					27.1	16.2	2.77				
	13	-360.8	CLAY (CL)					31.0	17.5	2.75				
	14	-359.3	CLAY (CL)					25.7	14.4	2.75				
	15	-357.8	CLAY (CL)					41.8	16.6	2.79				
	16	-356.3	CLAY (CL)					39.5	19.5	2.78				

ABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

RAL ENSITY U FT	COMPACTION DATA OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	SHEAR DATA INITIAL e	DRY DENSITY LBS CU FT	w_i %	w_F %	S_i %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	PERMEA e	
.7																
			1.521	63.1	58.6		98.3	TC	1.38 X 2.95	Q	0.5	1.05	0.20			
			1.552	62.4	59.6		97.9		1.39 X 2.95	Q	1.0	1.71	0.34			
			1.839	56.0	70.8		98.2		1.38 X 2.96	Q	2.0	2.93	0.41			
			1.807	56.7	70.0		98.7		1.39 X 2.96	Q	4.0	4.89	0.44	C-0.35 AVERAGE		
			0.531	112.5	19.1		99.3	TC	1.40 X 2.95	Q	0.5	2.07	0.78			
			0.516	113.2	18.8		100	TC	1.40 X 2.93	Q	0.5	2.04	0.77			
.3							97.9								0.512	1
.4							96.9								0.511	39
			0.496	115.5	17.7		98.8	TC	1.38 X 2.96	Q	0.5	4.33	1.92			
			0.547	111.7	19.4		98.5	TC	1.41 X 2.94	Q	0.5	3.12				
			0.516	114.0	18.4		98.9		1.41 X 2.94	Q	1.0	3.09				
			0.523	113.5	18.7		98.9		1.42 X 2.96	Q	2.0	5.40				
			0.544	111.9	19.4		99.0		1.36 X 2.96	Q	4.0	7.10	1.40			
			0.570	110.5	20.2		98.5	TC	1.39 X 2.95	Q	0.5	2.61	1.06			
			0.636	105.7	22.7		98.9	TC	1.38 X 2.96	Q	0.5	1.89	0.70			
			0.678	103.4	23.7		97.1	TC	1.38 X 2.95	Q	0.5	0.87	0.15			
			0.566	110.8	19.7		96.8	TC	1.37 X 2.91	Q	0.5	0.94	0.22			
			0.696	101.9	24.9		99.1	TC	1.38 X 2.96	Q	0.5	1.31	0.40			
			0.682	102.8	24.3		98.7	TC	1.39 X 2.96	Q	0.5	1.10	0.30			
			0.710	100.3	25.6		99.2	TC	1.37 X 2.94	Q	0.5	0.90	0.20			
			0.652	103.8	23.6		99.5	TC	1.41 X 2.93	Q	0.5	1.01	0.26			
			1.096	83.0	38.4		97.7	TC	1.40 X 2.94	Q	0.5	0.74	0.12			
			1.047	84.7	37.6		99.9	TC	1.39 X 2.93	Q	0.5	0.72	0.11			

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Undrained
CD – Co
CU – Co

			PERMEABILITY		CONSOLIDATION DATA				
σ_1 SQ FT	c T SQ FT	ϕ DEGREES	e	K_{20} FT MIN $\times 10^{-9}$	P_o T SQ FT	P_c T SQ FT	C_c	t_{50} •	REMARKS
.05	0.20								
.71	0.34								
.93	0.41								
.89	0.44	C-0.35	AVERAGE						
.07	0.78								
.04	0.77								
			0.512	114.2					VERTICAL
			0.511	396.2					HORIZONTAL
.33	1.92								
.12									
.09									
.40									
.10	1.40								
.61	1.06								
.89	0.70								
.87	0.16								
.94	0.22								
.31	0.40								
.10	0.30								
.90	0.20								
.01	0.26								
.74	0.12								
.72	0.11								

ect Shear   CD – Consolidated Drained   • Values at Pressure   T/SQ FT

onsolidate Undrained   CU – Consolidated Undrained

TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION OPT WATER %	MAX DRY D LBS
RUDC-16	17	355.3-353.8	CLAY (CL)								28.0	94.5		
			CLAY (CL)					26.3	15.9	2.76	27.6	94.6		
	18	-352.3	SILTY CLAY (CL-ML)					22.1	16.3		21.2			
	20A	350.8-349.3	CLAY (CL)					30.5	16.2	2.76				
	21	-347.8	CLAY (CL)					26.5	16.8	2.75				
	22	-346.3	CLAY (CL)					29.3	15.8	2.76				
	23	-345.0	SILT (ML)					(N-P)						
	25	343.3-341.8	CLAY (CL)					35.3	16.8	2.77				
	26	-340.3	CLAY (CL)					34.1	15.6	2.77				
	27	-338.8	CLAY (CL)					41.4	18.9	2.79				
	28	-337.3	CLAY (CL)					32.3	16.0	2.78				
	29	-335.8	CLAY (CL)					32.6	16.1	2.76				
	30	-334.3	SILT (ML)					17.0	13.4	2.75				
	31	-333.1	CLAY (CL)					24.4	15.0					

ENG FORM 1 MAR 58 2086 (PREVIOUS EDITIONS MAY BE USED) (EM 1110-2-1803) (TRANSLUCENT)

BLE B3 TEST DATA SUMMARY

[illegible]

T [illegible] Compressio[illegible]   [illegible]   C [illegible]

U [illegible] Unconfine[illegible] Compressio[illegible]   U [illegible] Unconsolidat[illegible] Undraine[illegible]   [illegible]

					PERMEABILITY		CONSOLIDATION DATA				
TEST	σ_m T/SQ FT	σ_1 T/SQ FT	c T/SQ FT	ϕ DEGREES	e	K_{20} FT/MIN $\times 10^{-9}$	P_o T/SQ FT	P_c T/SQ FT	C_c	t_{50} •	REMARKS
					0.822	158.1					VERTICAL
					0.821	2851.4					HORIZONTAL
Q	0.5	0.95									
	1.0	1.40									
	2.0	2.52									
	4.0	4.50	0.23								
Q	0.5	0.86	0.18								
Q	0.5	0.99	0.25								
Q	0.5	0.84	0.170								
Q	0.5	0.93	0.22								
Q	0.5	0.83	0.17								
Q	0.5	0.83	0.17								
Q	0.5	0.75	0.13								
Q	1.0	3.66	1.33								
	2.0	6.43	2.22								
	4.0	10.22	3.12								
		AV.	0.45	22.36							

...ion DS – Direct Shear CD – Consolidated Drained • Values at Pressure T/SQ FT

...ssion UU – Unconsolidate Undrained CU – Consolidated Undrained

TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION OPT WATER %	MAX DRY D LBS/
RUDC-17B	1	397.2-395.7	CLAY (CL)					33.9	17.7	2.77				
EL. 398.7														
	2	-394.2	CLAY (CL)					-	-	2.77				
	3	-392.7	CLAY (CL)					31.2	15.7	2.76				
	5	391.2-389.7	CLAY (CL)					42.2	16.7	2.78				
										2.78	21.0	108.5		
										2.78	20.5	108.5		
	6	-388.2	CLAY (CL)					44.0	19.5	2.80				
	9	385.2-383.7	CLAY (CL)					42.1	17.2	2.77				
	10	-382.2	CLAY (CL)					-	-	2.77				
	11	-380.7	CLAY (CL)					43.9	20.0	2.78				
	12	-379.2	CLAY (CL)					-	-	2.78				
	13	-377.7	CLAY (CL)					42.6	19.0	2.78				
	14	-376.2	CLAY (CL)					37.9	17.4	2.78				
	15	-374.2	CLAY (CL)					-	-	2.76				
	16	-373.2	CLAY (CH)					53.3	21.7	2.79				
	17	-371.7	CLAY (CH)					-	-	2.77				
											23.6	102.9		
											26.8	97.4		
	18	-370.2	SILT (ML)					(N-P)		2.74				
	19	-368.7	CLAY (CL)					27.2	14.7	2.76				

E B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

OMPACTION DATA		SHEAR DATA												PERMEABILITY	
PT. TER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL e	DRY DENSITY LBS CU FT	w_i %	w_F %	S_i %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	e	K_{20} FT MIN $\times 10^{-9}$
		0.504	114.9	16.4		90.2	TC	1.39 X 2.96	Q	0.5	2.56	1.03			
		0.496	115.5	16.9		94.3	TC	1.39 X 2.97	Q	0.5	3.54	1.52			
		0.547	111.3	17.5		88.3	TC	1.36 X 2.97	Q	0.5	2.36	0.93			
		0.672	103.8	21.6		89.4	TC	1.39 X 2.96	Q	0.5	1.66	0.58			
						97.6								0.599	74.2
						95.5								0.599	136.2
		0.660	105.2	22.8		96.7	TC	1.40 X 2.95	Q	0.5	2.87	1.18			
		0.724	100.3	26.1		99.8	TC	1.40 X 2.95	Q	0.5	2.44	0.97			
		0.772	97.5	27.8		99.8	TC	1.39 X 2.94	Q	0.5	1.90	0.70			
		0.798	96.5	28.5		99.3	TC	1.49 X 2.94	Q	0.5	2.00	0.75			
		0.738	99.8	26.3		99.0	TC	1.40 X 2.93	Q	0.5	2.42	0.96			
		0.868	98.9	30.9		92.9	TC	1.40 X 2.91	Q	0.5	0.64	0.07			
		0.776	97.7	27.6		98.9	TC	1.39 X 2.95	Q	0.5	1.36	0.43			
		0.766	97.5	27.3		98.4	TC	1.39 X 2.90	Q	0.5	0.75	0.12			
		1.248	77.4	44.6		99.7	TC	1.39 X 2.96	Q	0.5	1.25	0.38			
		0.941	89.0	33.7		99.2	TC	1.40 X 2.94	Q	0.5	0.93	0.22			
														0.679	304.1
														0.774	242.3
		0.595	107.2	21.0		96.8	TC	1.39 X 2.89	Q	0.5	3.36	1.43			
		0.557	110.6	19.5		96.5	TC	1.39 X 2.95	Q	1.0	1.80	0.40			
		0.588	108.5	21.1		99.1		1.38 X 2.95		2.0	2.89	0.45			
		0.591	108.2	21.3		99.5		1.38 X 2.97		4.0	5.29	0.65			
		0.563	110.2	20.2		99.0		1.39 X 2.96		6.0	7.34	0.67			
												AV. C-0.45			

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Undrained
CD – Consolid
CU – Consolid

Sheet 4 of 10

σ_m T/SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	PERMEABILITY e	PERMEABILITY K_{20} FT MIN $\times 10^{-9}$	CONSOLIDATION DATA P_o T SQ FT	CONSOLIDATION DATA P_c T SQ FT	CONSOLIDATION DATA C_c	CONSOLIDATION DATA t_{50} *	REMARKS
0.5	2.56	1.03								
0.5	3.54	1.52								
0.5	2.36	0.93								
0.5	1.66	0.58								
				0.599	74.2					VERTICAL
				0.599	136.2					HORIZONTAL
0.5	2.87	1.18								
0.5	2.44	0.97								
0.5	1.90	0.70								
0.5	2.00	0.75								
0.5	2.42	0.96								
0.5	0.64	0.07								
0.5	1.36	0.43								
0.5	0.75	0.12								
0.5	1.25	0.38								
0.5	0.93	0.22								
				0.679	304.1					VERTICAL
				0.774	242.3					HORIZONTAL
0.5	3.36	1.43								
1.0	1.80	0.40								
2.0	2.89	0.45								
4.0	5.29	0.65								
6.0	7.34	0.67								
		AV. C-0.45								

DS – Direct Shear
UU – Unconsolidate Undrained
CD – Consolidated Drained
CU – Consolidated Undrained
* Values at Pressure T/SQ FT

TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION OPT WATER %	MAX DRY D LBS/
RUDC-17B	20	368.7-367.2	SILT (ML)					(N-P)		2.72				
	21	-365.7	CLAY (CL)					32.9	16.3	2.80				
	23	364.2-362.7	CLAY (CL)					-	-	2.76				
	25	361.2-359.7	CLAY (CL)					36.2	15.3	2.77				
RUDC-28	1	569.5-568.0	CLAY (CL)					47.1	21.8	2.78				
EL. 575.0														
	2	-566.5	CLAY (CL)					45.2	19.5	2.80				
	3	-565.0	CLAY (CL)					42.3	20.0	2.78				
											35.2	85.8		
											38.1	81.8		
	4	-563.5	CLAY (CL)					40.5	19.1	2.80				
	5	-562.0	CLAY (CL)					33.2	16.3	2.76				
	6	-560.5	SILTY SAND (SM)	30	32	38								
			GRAVELLY											

TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

AT. TER NT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	SHEAR DATA INITIAL e	DRY DENSITY LBS CU FT	w_i %	w_F %	S_i %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T SQ FT	σ_1 T/SQ FT	c T SQ FT	ϕ DEGRE
				0.490	113.9	17.5		97.1	TC	1.39 X 2.93	Q	0.5	1.48	0.49	
				0.636	106.9	21.8		96.1	TC	1.40 X 2.94	Q	0.5	1.14	0.32	
				0.740	99.0	26.7		99.5	TC	1.38 X 2.95	Q	0.5	1.01	0.26	
				0.849	93.5	30.6		99.8	TC	1.37 X 2.95	Q	0.5	1.06	0.26	
				0.724	100.6	25.1		96.4	TC	1.41 X 2.94	Q	0.5	1.40	0.45	
				0.957	89.3	33.5		98.1	TC	1.39 X 2.95	Q	0.5	0.95		
				0.957	89.3	33.8		98.8		1.40 X 2.94		1.0	1.77		
				0.958	89.2	33.7		98.5		1.39 X 2.94		2.0	2.60		
				0.961	89.1	33.8		98.5		1.40 X 2.94		4.0	5.40		
													C-0.40		
				1.137	81.2	40.5		99.0	TC	1.39 X 2.95	Q	0.5	0.89	0.20	
5.2	85.8														
8.1	81.8														
				1.126	82.2	39.6		98.4	TC	1.39 X 2.95	Q	0.5	0.81	0.15	
				0.925	89.4	31.0		92.5	TC	1.41 X 2.89	Q	0.5	0.59	0.045	

UCENT)

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Undrained

				PERMEABILITY		CONSOLIDATION DATA				
σ_m T/SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	e	K_{20} FT MIN $\times 10^{-9}$	P_o T SQ FT	P_c T SQ FT	C_c	t_{50}*	REMARKS
0.5	1.48	0.49								
0.5	1.14	0.32								
0.5	1.01	0.26								
0.5	1.06	0.26								
0.5	1.40	0.45								
0.5	0.95									
1.0	1.77									
2.0	2.60									
4.0	5.40									
	C-0.40									
0.5	0.89	0.20								
				1.021	916.6					VERTICAL
				1.120	1435.6					HORIZONTAL
0.5	0.81	0.15								
0.5	0.59	0.045								

DS – Direct Shear
UU – Unconsolidate Undrained
CD – Consolidated Drained
CU – Consolidated Undrained
* Values at Pressure T/SQ FT

TABLE B3 TE

BORING NO.	SAM. NO.	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT. WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION DAT OPT WATER %	MAXIMUM DRY DENS LBS CU F
RUDC-29	1	570.5-569.0	CLAY (CL)					38.7	17.0	2.73				
EL. 572.0														
	2	-567.5	CLAY (CL-CH)					-	-	2.76				
	3	-566.0	CLAY (CL-CH)					48.7	21.7	2.79				
	4	-564.5								2.81	24.4	102.2		
			CLAY (CH)					56.3	22.7		23.1	104.5		
	5	-563.0	CLAY (CL)					46.7	20.9	2.80				
	6	-561.5	CLAY (CH)					52.8	23.4	2.81				
	7	-560.0	CLAY (CL-CH)					50.3	23.3	2.80				
	8	-558.5	CLAY (CL)					46.0	20.9	2.79				
	9	-557.0	CLAY (CL)					47.8	20.7	2.80				
	10	-555.5	CLAY (CL)					46.2	20.2	2.79				
	11	-554.0	CLAY (CL)					36.1	16.6	2.80				
	12	-552.5	CLAY (CL)					45.6	21.0	2.80	43.8	77.5		
											43.3	76.7		
	13	-551.0	CLAY (CL)					47.2	21.2	2.79				
	14	-549.5	CLAY (CL)					43.2	17.6	2.80				

BLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

COMPACTION DATA		SHEAR DATA												PERMEABILITY	
OPT WATER %	MAXIMUM DRY DENSITY LBS CU FT	INITIAL e	DRY DENSITY LBS CU FT	w_i %	w_F %	S_i %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T/SQ FT	σ_1 T/SQ FT	c T/SQ FT	ϕ DEGREES	e	FT X
		0.540	110.6	18.2		92.0	TC	1.41 X 2.94	Q	0.5	2.94	1.22			
		0.536	112.1	18.6		95.7	TC	1.39 X 2.94	Q	0.5	2.08	0.79			
		0.633	106.6	22.0		96.9	TC	1.37 X 2.95	Q	0.5	2.25	0.88			
														0.716	143.
														0.678	454.
		0.714	101.9	25.1		98.4	TC	1.36 X 2.95	Q	0.5	0.74				
		0.770	98.7	26.3		95.6		1.40 X 2.94		1.0	2.01				
		0.736	100.6	26.0		99.0		1.39 X 2.94		2.0	3.14				
		0.752	99.7	25.9		96.5		1.40 X 2.95		4.0	5.13	0.50			
		0.937	90.5	32.8		98.4	TC	1.41 X 2.93	Q	0.5	1.93	0.72			
		1.043	85.5	37.1		99.6	TC	1.40 X 2.95	Q	0.5	1.48	0.49			
		1.016	86.4	36.4		100	TC	1.39 X 2.95	Q	0.5	1.13	0.32			
		1.134	81.9	40.3		99.5	TC	1.39 X 2.95	Q	0.5	0.99	0.25			
		1.220	78.4	43.6		99.7	TC	1.39 X 2.95	Q	0.5	0.75	0.12			
		1.077	84.1	37.7		98.0	TC	1.40 X 2.93	Q	0.5	0.76	0.13			
														1.254	454
														1.277	690
		1.408	72.3	50.2		99.5	TC	1.38 X 2.95	Q	0.5	0.68	0.09			
		1.254	77.5	44.4		99.2	TC	1.38 X 2.95	Q	0.5	0.71	0.10			

TC – Triaxial Compression   DS – Direct Shear   CD – Co
UC – Unconfined Compression   UU – Unconsolidate Undrained   CU – Co

σ_1 T/SQ FT	c T/SQ FT	Ø DEGREES	PERMEABILITY e	PERMEABILITY K_{20} FT/MIN $\times 10^{-9}$	CONSOLIDATION DATA P_o T/SQ FT	CONSOLIDATION DATA P_c T/SQ FT	CONSOLIDATION DATA C_c	CONSOLIDATION DATA t_{50}	REMARKS
94	1.22								
08	0.79								
26	0.88								
			0.716	143.1					VERTICAL
			0.678	454.8					HORIZONTAL
74									ULTIMATE
01									ULTIMATE
14									ULTIMATE
13	0.50								ULTIMATE
93	0.72								
48	0.49								
13	0.32								
99	0.25								
75	0.12								
76	0.13								
			1.254	454.6					VERTICAL
			1.277	690.9					HORIZONTAL
68	0.09								
71	0.10								

st Shear CD – Consolidated Drained • Values at Pressure T SQ FT

nsolidate Undrained † CU – Consolidated Undrained

TABLE B3

BORING NO.	SAM NO.	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION D OPT WATER %	MAX DRY D LBS/
U66502	2	383.0-381.1	SILTY SAND (SM)	7	58	36				2.71	10.2	105.3		
EL.389.5														
	3	-379.4	SANDY CLAY (CL)								17.1	101.6		
								31	17	2.78	18.3	112.9		
	4	377.4-376.3	CLAY (CL)					33	17	2.76	19.3	109.3		
	5	374.3-372.0	CLAY (CL)					38	18	2.78				
	6	370.5-368.0	CLAY (CL)					37	16	2.78				
	7	365.6-363.6	CLAY (CL)					35	17	2.77				
	8	361.1-358.6	CLAY (CL)					37	16	2.77				
U66502	9	356.5-354.0	CLAY (CH)					52	21	2.80				
AUC67511	1	329.7-327.9	SANDY CLAY (CL)					28	18	2.72				
EL.331.7														
	2	326.2	SANDY CLAY (CL)					28	14	2.74				
	3	-324.8	SANDY CLAY (CL-ML)	GRAVELLY				19	13	2.72				
	4	324.5-322.8	SANDY CLAY (CL)					28	15	2.72				
	5	315.7-313.7	SANDY CLAY (CL)					22	13	2.73				

TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA: OPT WATER %	COMPACTION DATA: MAXIMUM DRY DENSITY LBS CU FT	SHEAR DATA: INITIAL e	DRY DENSITY LBS CU FT	w_i %	w_F %	S_i %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	PERM… e
105.3															
101.6															
112.9															
109.3			0.562	110.2	19.8		97.2	TC	1.36 X 2.94	Q	0.5	4.49	2.00		
			0.529	113.4	19.0		99.9	TC	1.33 X 2.94	Q	0.5	4.43	1.97		
			0.654	104.9	23.4		99.5	TC	1.34 X 2.95	Q	0.5	2.71	1.10		
			0.710	101.1	25.7		100	TC	1.39 X 2.95	Q	0.5	1.56	0.53		
			0.715	100.8	25.8		100	TC	1.40 X 2.92	Q	0.5	1.18	0.34		
			1.013	86.8	35.9		99.2	TC	1.37 X 2.95	Q	0.5	0.93	0.22		
			0.624	104.5	20.2		88	TC	1.37 X 2.97	Q	0.5	1.70	0.60		
			0.406	121.6	13.5		91	TC	1.45 X 2.92	Q	0.5	3.21	1.35		
			0.353	126.3	11.4	13.1	88.3								0.35
			0.402	121.2	11.7	14.1	79.7								0.40
			0.415	119.9	11.4		74.8	TC	1.39 X 2.95	Q	0.5	1.56	[illegible]		
			0.424	119.2	15.2		97.5	TC	1.39 X 2.95	Q	0.5	4.97	2.24		
			0.298	131.2	10.7		98.1								

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Undrained

E	TEST	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	PERMEABILITY e	PERMEABILITY K_{20} FT MIN $\times 10^{-9}$	CONSOLIDATION DATA P_o T SQ FT	CONSOLIDATION DATA P_c T SQ FT	CONSOLIDATION DATA c_c	CONSOLIDATION DATA t_{50} *	REMARKS
	Q	0.5	4.49	2.00								
	Q	0.5	4.43	1.97				0.70	0.90	0.045		SWELLING NOTED
	Q	0.5	2.71	1.10								
	Q	0.5	1.56	0.53				1.59	2.0	0.196		
	Q	0.5	1.18	0.34								
	Q	0.5	0.93	0.22				2.15	1.6	0.640		
	Q	0.5	1.70	0.60				0.10	1.7	0.08		
	Q	0.5	3.21	1.35								
						0.353	77.2					VERTICAL
						0.402	141.5					HORIZONTAL
	Q	0.5	1.86	0.68				0.385	0.80	0.032		
	Q	0.5	4.97	2.24								
								1.1	2.9	0.0365		SWELLING NOTED

DS – Direct Shear
UU – Unconsolidate Undrained
CD – Consolidated Drained
CU – Consolidated Undrained
* Values at Pressure T/SQ FT

TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION OPT WATER %	MAX DRY D LBS/
AUDC	1	264.9-262.4	SANDY CLAY (CL)					37	20	2.74				
67515														
EL. 265.9	2	-260.4	SANDY CLAY (CL)					35	19	2.75				
	3	259.9-257.7	CLAY (CL)					36	19	2.76				
	4	256.9-255.9	CLAY (CL)					40	19	2.76				
AUDC														
67515	5	254.4-252.2	CLAY (CL)					39	19	2.74				
AUC	1	311.3-300.4	CLAY (CL)					34	20	2.73				
67516														
EL. 313.3	2	308.8-307.3	CLAY (CL)					28	16	2.75				
	3	-305.1	SANDY CLAY (CL)					37	18	2.73				
AUC														
67516	4	-302.3	CLAY (CL)					32	18	2.74				

TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY

[NA]TURAL DENSITY [LB]/CU FT	COMPACTION DATA: OPT WATER %	COMPACTION DATA: MAXIMUM DRY DENSITY LBS CU FT	SHEAR DATA: INITIAL e	DRY DENSITY LBS CU FT	w_i %	w_F %	S_i %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	PERME[ABILITY]: e	
			0.725	99.1	24.4	23.9	92.2									
			0.593	107.7	19.4		89.9	TC	1.43 X 2.97	Q	0.5	1.99	0.75			
				106.2	20.3	21.7	90.7								0.616	
				107.7	18.8	21.6	87.2								0.593	5
			0.718	100.3	24.0		92.3	TC	2.81 X 6.34	Q	0.5	2.0	0.75			
			0.654	104.1	18.4	22.8	77.5									
			0.859	92.6	30.6		98.3	TC	1.43 X 2.91	Q	0.5	1.95	0.78			
			0.837	93.1	29.9		97.9	TC	1.40 X 2.93	Q	0.5	1.25	0.38			
			0.857	91.3	31.3	24.9	100									
			0.770	96.3	25.9		91.8	TC	1.40 X 2.96	Q	0.5	1.50	0.50			
			0.603	106.3	20.1	20.9	91.0									
			0.551	110.6	18.9		94.4	TC	1.36 X 2.91	Q	0.5	2.51	1.00			
				105.2	21.5	22.6	93.5								0.632	
				106.9	20.3	21.3	92.3								0.605	
			0.682	101.3	25.5		100	TC	1.40 X 2.95	Q	0.5	1.77	0.64			
			0.645	103.6	23.1	22.9	97.6									
			0.643	104.1	23.4		99.8	TC	1.40 X 2.97	Q	0.5	1.92	0.71			
			0.676	102.0	24.6	23.0	99.7									

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Undrained
CD [cut off]
CU [cut off]

EST	σ_m T SQ FT	σ_1 T SQ FT	c T SQ FT	ϕ DEGREES	PERMEABILITY e	PERMEABILITY K_{20} FT/MIN $\times 10^{-9}$	CONSOLIDATION DATA P_o T/SQ FT	CONSOLIDATION DATA P_c T/SQ FT	CONSOLIDATION DATA C_c	CONSOLIDATION DATA t_{50} *	REMARKS
							0.05	2.8	0.134		
	0.5	1.99	0.75								
					0.616	7358					VERTICAL
					0.593	50,490					HORIZONTAL
	0.5	2.0	0.75								
							0.31	2.8	0.055		SWELLING NOTED
	0.5	1.95	0.78								
	0.5	1.25	0.38								
							0.58	4.5	0.246		
	0.5	1.50	0.50								
							0.1	1.6	0.0684		
	0.5	2.51	1.00								
					0.632	999.9					
					0.605	1397.3					
	0.5	1.77	0.64								
							0.31	4.1	0.0963		SWELLING NOTED
	0.5	1.92	0.71								
							0.35	4.2	0.134		

DS – Direct Shear
UU – Unconsolidate Undrained
CD – Consolidated Drained
CU – Consolidated Undrained
* Values at Pressure T/SQ FT

TABLE B3

PROJECT LAKE ERIE - LAKE ONTARIO WATERWAY PROJECT

IDENTIFICATION DATA			
Boring No.	Sam No.	Depth or Elevation of Sample	Geologist's Classification
			The 12 samples were examined and all were found to be reasonably similar
			in gross texture and composition. The following classification is applicable for
			each of the 12 samples received from hole ss-5A.
			O.R.D DESCRIPTION (1963)
SS-5A	1	15.7-16.3	The rock is a maroon - grading to green colored CLAYSTONE. It is
	2	16.3-17.1	very even textured, massive, dense, compact and very fine grained. It is
	3	18.1-18.8	nonfissile only poorly laminated thus it is <u>not</u> classified as shale. The rock
	4	21.7-22.9	is composed almost wholly of clay-size grains with only a small amount of
			quartz silt. It is indurated or cemented by evenly distributed carbonate-
	5	28.1-28.7	probably calcite. The rock contains occasional slickenside compaction planes.
	6	30.6-31.6	There appears to be no significant difference in hardness, grain size or
	7	31.6-32.4	toughness of the maroon portion and green portion of the rock. The
	8	33.7-34.3	color variation is believed due to degree of oxidation in the sediment. The
	9	50.0-51.3	rock will weather as a claystone or indurated mudstone in that irregular
	10	51.3-52.8	or oblique cracks will develop about as readily as cracks which parallel
			bedding. The rock will break down into chunks as compared to a clay
			SHALE which would break down in sheets and flakes
	11	62.8-64.4	
	12	64.4-66.1	

TABLE B3 SUMMARY OF ROCK CORE TESTS

CT FEATURE 6" CORE FROM HOLE SS-5A

	STRENGTH TEST DATA in pounds per square inch								COMPUTED DATA						
	Compression			SHEAR DATA			Sliding Friction						Specific Gravity		
	Unit Load at Failure	Break Angle Degrees	Tensile	Normal Unit Load	Direct Unit Load of Failure	MAX RESIST TO SLIDING *	Type of Test	Angle Degrees	Modulus of Elasticity "E", 10^6 psi	Angle of Internal Friction ø Degrees	Cohesion "C" psi	Field Water Content %	Gs	Ga	Gm
e reasonably similar															
tion is applicable for															
LAYSTONE. It is				50	307	266*									
fine grained. It is				100	398	328*	ROCK ON ROCK	30.4	(on sheared surface) - see Fig. 1						
as shale. The rock				150	483	386*									
small amount of	2495								0.362	- see Fig. 2		2.5			
ibuted carbonate-									0.415						
compaction planes.				50		28.5*	ROCK ON ROCK								
ness, grain size or	2979								1.068	see Fig. 3		4.3			
the rock. The				100		58.1*	ROCK ON ROCK								
the sediment. The				150		94.6*	ROCK ON ROCK	30.6	(on smooth surface) - see Fig. 4						
ne in that irregular	5273	(compressive strength ⊥ to grain)										1.9			
acks which parallel															
ared to a clay				50		32.9*									
.				100	see note below	63.6*	CONCRETE ON ROCK	32.4	(on smooth surface) - see Fig. 5						
				150		91.5*									
					Note: The stress required to break the bond between the concrete a										
	6027	(compressive strength ⊥ to grain)													
	4612	(compressive strength ∥ to grain)										1.9			

O... Qu...

SHEET 9 OF 10

O.R.D. LAB. TESTS
Queenston Shale

DATE MAY 1963

ATA	PHYSICAL PROPERTIES										
Cohesion "C" psi	Field Water Content %	Specific Gravity			Total Absorption %	Void Ratio	Porosity	Unit Dry Weight lb/cu ft	Weathering Characteristics		REMARKS PHOTOGRAPH NO.
		Gs	Ga	Gm							
surface) - see Fig. 1											102/63.535 X.1
ig. 2	2.5							160.5			102/63.535 X.2,3
ig. 3	4.3							159.0			102/63,535 X.4,5
urface) - see Fig. 4											
	1.9							164.0			
urface) - see Fig. 5											
bond between the concrete and rock under 100psi normal load was 74.4 psi											
											102/63.535 X.6,7
	1.9							164.2			102/63.535 X.8,9

TABLE B3

BORING NO.	SAM. NO.	DEPTH OR ELEV. OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT. WATER CONT %	NATURAL DRY DENSITY LBS CU FT	COMPACTION D... OPT WATER %	MAX DRY D... LBS/...
C-66501	1	199.2-198.2								2.76				
	4	193.1-192.0								2.80				
	11	181.8-180.7								2.79				
	13	179.2-177.6								2.79				
	15	174.1-172.7								2.78				
	17	170.7-169.8								2.75				
	19	168.9-167.6								2.79				
	20	166.0-165.0								2.79				
	22	160.9-159.6								2.76				
	8	186.4-184.9								2.77				
	3	197.4-196.6								2.77				
	5	192.0-190.9								2.78				
	9	183.6-182.6								2.78				
	10	182.6-181.8								2.78				
	12	180.7-179.7								2.79				
	14	176.9-175.6								2.77				
	16	172.6-171.6								2.78				
	18	169.8-168.9								2.77				
	20	167.0-166.0								2.79				
	24	157.9-156.9								2.76				

TABLE B3 TEST DATA SUMMARY

FEATURE LAKE ERIE - LAKE ONTARIO WATERWAY - CYCLIC LOADING ON QUEENSTON SH

...IC ...TY	NAT. WATER CONT. %	NATURAL DRY DENSITY LBS CU FT	COMPACTION DATA OPT. WATER %	MAXIMUM DRY DENSITY LBS CU FT	SHEAR DATA INITIAL e	DRY DENSITY LBS CU FT	w_1 %	w_F %	S_1 %	TYPE TEST	SPECIMEN SIZE INCHES	TEST	σ_m T/SQ FT	σ_I T/SQ FT
6					0.041	165.4	1.0	1.2	100	TC	5.84 X10.35	SU	1.0-6.0	1.0-35.0
0					0.057	165.3	1.0						1.0-6.0	1.0-45.0
9					0.048	166.1	1.0	1.7	58.1	TC	5.86 X 12.1	SU	1.0-6.0	1.0-25.0
9					0.052	165 4	1.2	2.27	63.9	TC	5.85 X 13.27	SU	1.0-6 0	1.0-15.0
8					0.039	167.0	1.0	1.54	71.3	TC	5.88 X 12.92	SU	1.0-6.0	1.0-15.0
5					0.033	166.1	1.0	1.2	83.7	TC	5 86 X 10.55	SU	1.0-6.0	1.0-25.0
9					0.056	164.9	1.0	2.2	50.1	TC	5.89 X 13.35	SU	1.0-6.0	1.0-35.0
9					0.051	165.6	1.0	1.8	54.3	TC	5.93 X 11.58	SU	1.0-6.0	1.0-45.0
6					0.041	165.4	1.0	1.5	67.2	TC	5.84 X 13.08	SU	1.0-6.0	1.0-45.0
7					0.044	165.6	1.0	1.6	63.3	TC	5.85 X 13.20	SU	1.0-6.0	1.0-25.0
7					0.045	165.4	1.0	1.8	61.8	TC	5.82 X 8.48	SU	0	0
8					0.053	164.7	1.1	2.4	60.0	TC	5.81 X 13.14	SU	0	0
8					0.050	165.3	1.0	2.0	55.9	TC	5.85 X 11.15	SU	0	0
8					0.057	165.8	1.0	2.2	100	TC	5.86 X 8.88	SU	0	0
9					0.054	165.3	1.0	2.2	52.1	TC	5.87 X 10.35	SU	0	0
7					0.043	165.7	1.0	2 0	64.3	TC	5.87 X 10.50	SU	0	0
8					0.042	166.4	1.0	2.2	65.5	TC	5.86 X 9.84	SU	0	0
7					0.040	166.2	1.0	1.6	69.6	TC	5.88 X 9.31	SU	0	0
9					0.046	166.5	1.0	1.9	61.3	TC	5.89 X 12.05	SU	0	0
6					0.044	164.9	1.0	1.9	62.3	TC	5.87 X 10.1	SU	0	0

TC – Triaxial Compression
UC – Unconfined Compression
DS – Direct Shear
UU – Unconsolidate Und

CLIC LOADING ON QUEENSTON SHALE

E	TEST	σ_m T/SQ FT	σ_I T/SQ FT	C T/SQ FT	CYCLES LENGTH	CYCLES TOTAL	CONSOLIDATION DATA P_o T SQ FT	P_c T SQ FT	C_c	t_{50} *	REMARKS
5	SU	1.0-6.0	1.0-35.0	237.0	10 MIN	62.472					σ_m & σ_I ARE THE
											MIN & MAX PRESSURES
		1.0-6.0	1.0-45.0		LOST IN CYCLING DUE TO POOR PREPARATION						DURINC CYCLING
											SAMPLES WERE SHEAR-
1	SU	1.0-6.0	1.0-25.0	192.3	10 MIN	54.437					ED AT σ_m =1TSF
27	SU	1.0-6.0	1.0-15.0	123.6	10 MIN	66.071					
92	SU	1.0-6.0	1.0-15.0	202.0	10 MIN.	63.342					
55	SU	1.0-6.0	1.0-25.0	135.3	10 MIN.	58.740					
35	SU	1.0-6.0	1.0-35.0	207.9	10 MIN	61.452					
58	SU	1.0-6.0	1.0-45.0	160.3	10 MIN	65.364					
08	SU	1.0-6.0	1.0-45.0	161.8	10 MIN	52.212					
20	SU	1.0-6.0	1.0-25.0	192.6	26 MIN	30.876					
	SU	0	0	167.3	0	0	SATURATED 36 DAYS				
4	SU	0	0	137.2	0	0	SATURATED 54 DAYS				
15	SU	0	0	122.3	0	0	SATURATED 45 DAYS				
	SU	0	0	181.5	0	0	SATURATED 34 DAYS				
5	SU	0	0	205.7	0	0	SATURATED 34 DAYS				
0	SU	0	0	101.1	0	0	SATURATED 35 DAYS				
	SU	0	0	68.3	0	0	SATURATED 38 DAYS				
	SU	0	0	125.6	0	0	SATURATED 35 DAYS				
5	SU	0	0	118.2	0	0	SATURATED 32 DAYS				
	SU	0	0	113.0	0	0	SATURATED 35 DAYS				

ion — DS – Direct Shear — CD – Consolidated Drained — • Values at Pressure T SQ FT

ession — UU – Unconsolidate Undrained — CU – Consolidated Undrained

SU - Slow Undrained

GENERALIZED GEOLOGIC COLUMN

SYSTEM	GROUP	FORMATION	MEMBER	AVERAGE THICKNESS	SYMBOL	GENERAL DESCRIPTION
QUATERNARY					OB	TILL, LACUSTRINE, AND BEACH DEPOSITS: CLAYS, SILTS, SANDS, AND GRAVELS, RED TO RED-BROWN, GRAY.
SILURIAN	BERTIE	BERTIE	SCAJAQUADA	7'	Sbs	SHALE: THIN-BEDDED: DOLOMITIC; MODERATELY-HARD; BLUISH-GRAY TO BLACK.
SILURIAN	BERTIE	BERTIE	FALKIRK	26'	Sbf	DOLOMITE: THIN-BEDDED; VERY ARGILLACEOUS, GYPSIFEROUS, SHALE BEDS THROUGHOUT, NUMEROUS GYPSUM BAND, BEDS, AND NODULES THROUGHOUT; SOFT TO HARD; DENSE; LIGHT-BROWN TO DARK-GRAY.
SILURIAN	BERTIE	BERTIE	OATKA	23'	Sbo	DOLOMITE: THIN-BEDDED; ARGILLACEOUS, GYPSIFEROUS, SHALE BEDS THROUGHOUT; SOFT TO MODERATELY-HARD; DENSE; LIGHT-BROWN TO DARK-GRAY.
SILURIAN	SALINA	CAMILLUS		400'	Sc	SHALE: THIN-BEDDED TO MASSIVE; GYPSIFEROUS; SOFT TO MODERATELY-HARD; GRAY TO BROWNISH-GRAY.
SILURIAN	LOCKPORT	LOCKPORT		+140	Sl	DOLOMITE AND DOLOMITE LIMESTONE: THIN-BEDDED TO MASSIVE; ARGILLACEOUS TO SHALY, OCCASIONAL CALCITE AND GYPSUM PARTINGS, OCCASIONAL CARBONACEOUS AND SHALY PARTINGS, CHERT NODULES; MODERATELY-HARD TO HARD; DENSE TO FINE-CRYSTALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) THAT ARE OCCASIONALLY STAINED AND WIDENED BY SOLUTION ACTION, OCCASIONAL MINERALIZED SOLUTION PITS AND VUGS; VARIOUS SHADES OF GRAY.
SILURIAN	CLINTON	ROCHESTER		62'	Sr	SHALE: LAMINATED TO BLOCKY; UPPER IS SLIGHTLY CALCAREOUS WITH OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE, LOWER IS SLIGHTLY CALCAREOUS WITH BANDS AND THIN BEDS OF LIMESTONE, OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN); DARK-GRAY.
SILURIAN	CLINTON	IRONDEQUOIT		18'	Si	LIMESTONE: MEDIUM-BEDDED TO MASSIVE; OCCASIONAL SHALE PARTINGS; MODERATELY-HARD TO HARD; DENSE TO CRYSTALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) SOME WIDENED BY SOLUTION ACTION, OCCASIONAL VUGS; LIGHT-TO MEDIUM-GRAY.
SILURIAN	CLINTON	REYNALES		5'	Sre	LIMESTONE: THIN-BEDDED; ARGILLACEOUS, SLIGHTLY-CALCAREOUS; MODERATELY-HARD TO HARD; FINE-CRYSTALLINE TO CRYSTALLINE; GRAY.
SILURIAN	CLINTON	NEAHGA		6'	Sn	SHALE: PLATY; SLIGHTLY-SILTY, SLIGHTLY-CALCAREOUS, WAXY, OCCASIONAL GYPSUM PARTINGS ALONG BEDDING PLANES; SOFT; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) OCCASIONALLY STAINED AND OCCASIONALLY FILLED WITH PYRITE; GREENISH-GRAY.
SILURIAN	MEDINA	THOROLD		6'	Sf	SANDSTONE TO SILTSTONE: MEDIUM-BEDDED TO MASSIVE; QUARTZITIC WITH QUARTZ GRAINS (ANGULAR TO SUB-ANGULAR) CEMENTED WITH SILICA, OCCASIONAL SHALE AND GYPSUM PARTINGS; HARD; FINE-GRAINED; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE STAINED, SOME SLIGHTLY OPEN; LIGHT-GRAY.
SILURIAN	MEDINA	GRIMSBY		50'	Sg	SILTSTONE AND SANDSTONE: INTERBEDDED WITH SHALE AND SANDSTONE; MODERATELY-HARD TO HARD; FINE-TO MEDIUM-GRAINED; CONTAINS OCCASIONAL JOINTS AND FRACTURES (TIGHT TO OPEN); PINK, WHITE, OR PALE-GREEN, MOTTLED SILTSTONE OR SANDSTONE WITH RED SHALE AND RED SANDSTONE INTERBEDS.
SILURIAN	MEDINA	POWER GLEN		35'	Sp	SHALE: LAMINATED TO PLATY; ARGILLACEOUS WITH OCCASIONAL THIN CALCAREOUS SILTSTONE BEDS; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE OCCASIONALLY SLIGHTLY STAINED AND OCCASIONALLY OPEN; GRAYISH-GREEN WITH LIGHT-TO MEDIUM-GRAY SILTSTONE.
SILURIAN	MEDINA	[illegible]				SANDSTONE: MEDIUM-BEDDED TO MASSIVE; CROSS-BEDDED; QUARTZITIC, OCCASIONAL INCLUSIONS OF GREEN SHALE; HARD; [illegible]

AY.

UM BAND. BEDS, AND

-HARD: DENSE:

CALCITE AND GYPSUM
; DENSE TO FINE-CRYS-
ENED BY SOLUTION

ONG LAMINAE. LOWER
ONG LAMINAE:

NSE TO CRYSTALLINE:
GS: LIGHT-TO

YSTALLINE TO

EDDING PLANES: SOFT:
ITH PYRITE:

SUB-ANGULAR)
ASIONAL JOINTS

E-TO MEDIUM-GRAINED;
ED SILTSTONE OR SANDSTONE

IGHTLY-SOFT TO
AINED AND OCCASIONALLY

ABBREVIATIONS

@	at	la	low angle
alt	alternating	lam	laminated, laminae
ang	angular	lea	leached
an	anhydrite	lig	lignite
ar	argillaceous	ln	lean
bdd	bed, bedded, bedding	*ls	limestone
bdr	bedrock	lt	light
bky	blocky	lo	loose
bl	blue	L.C.	lost core
bld	boulder	L.D.W.	lost drill water
blk	black	med	medium
brec	brecciated	mic	micaneous
brn	brown	min	mineralized
buf	buff	mod	moderate, moderately
c	coarse	mss	massive
calc	calcareous	mst	moist
carb	carbonaceous	mtl	material
cav(s)	cavity	muc	mucky
cbl	cobble	nod	nodules
*cht	chert	num	numerous
circl	circulation	occ	occasinally, occasional
cl	clay, clayey	op	open
cmtd	cemented	org	organic
col	columnar	pit	pit, pitted, pitting
conc	concretions	pl	plastic
cong	conglomerate	pla	platy
crm	crumbly	pln	plane
d	dense	ptg(s)	parting, partings
dk	dark	*qtz	quartzite, quartz
dmp	damp	rnd	round, rounded
*dol	dolomite, dolomitic	sat	saturated
ext	extremely	scat	scattered
f	fine, finely	sd	sand, sandy
fe	iron	*sh	shale, shaly
fld	filled	si	silt, silty
fm	firm	*sis	siltstone
fos	fossil, fossilferous	sl	slightly
frac(s)	fractures	slcs	siliceous
frag	fragments	slks	slickensides
fri	friable	so	soft
fsl	fissile	ss	sandstone
gen	generally	st	stiained, staining
gr	grain	stf	stiff
gra	gradation	v	very
grn	green	var	variegated
grv	gravel, gravelly	vert	vertical
gry	gray	vgy	vuggy
*gyp	gypsum	w	water
ha	high angle	w/	with
*hal	halite	wea	weathered
hd	hard	wht	white
hor	horizontal	x-bdd	cross bedded
inbd	interbedded	xln	crystalline
incl	inclusions	y	yellow
irr	irregular		
jt	joint		

*WHEN USED AS LOG SYMBOL FIRST LETTER IS CAPITALIZED

HOLE NUMBER —
*OFFSET FROM (

ELEVATION AN

OVERBURDEN —

LOST CORE —
PERCENT CORE
DIAMETER OF
DATE BORING (

*OFFSET FROM F

I KNOWN SOFT ZON
II PROBABLE SOFT
III POSSIBLE SOFT

UNIFIED SOIL CLASSIFICATION SYSTEM

GW GRAVEL OR SANDY GRAVEL, WELL GRADED

GP GRAVEL OR SANDY GRAVEL, POORLY GRADED

GM SILTY GRAVEL, OR SILTY SANDY GRAVEL

GC CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL

SW SAND OR GRAVELLY SAND, WELL GRADED

SP SAND OR GRAVELLY SAND, POORLY GRADED

SM SILTY SAND OR SILTY GRAVELLY SAND

SC CLAYEY SAND OR CLAYEY GRAVELLY SAND

ML SILTS, SANDY SILTS, GRAVELLY SIL

CL LEAN CLAYS, SANDY CLAYS, OR GRAV

OL ORGANIC SILT, OR LEAN OR AN

MH MICACEOUS

NOTE:

AD-A100 739 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2
REVIEW OF REPORTS ON LAKE ERIE-LAKE ONTARIO WATERWAY, NEW YORK.--ETC(U)
OCT 73

UNCLASSIFIED NL

2 OF 3
AD A
100739

LEGEND FOR LOGS OF BORINGS

HOLE NUMBER → AUDC-67512
*OFFSET FROM CENTER LINE OF CANAL → 100'LT
ELEVATION AND DATE WATER LEVEL OBSERVED → ▼W 10-7-60
OVERBURDEN → OB
LOST CORE → L.C. 0.8'
PERCENT CORE RECOVERED IN BEDROCK → 95%
DIAMETER OF BEDROCK CORE → 2 1/8"
DATE BORING COMPLETED → 1-16-63

*OFFSET FROM PROFILE MAYBE RIGHT OR LEFT AS DEFINED.

TYPE OF EXPLORATION CODE DESIGNATION

A - AUGER HOLE - HAND OR POWER AUGER
U - UNDISTURBED SAMPLE HOLE
D - DRIVE SAMPLE HOLE
C - CORE HOLE
R - ROCK BIT HOLE
P - PROBING
SI - SQUAW ISLAND BORINGS
● - VERTICAL PROBINGS
⬤ - VERTICAL BORINGS

SOFT ZONE CLASSIFICATION

I KNOWN SOFT ZONE - GOOD EVIDENCE OF ZONE IN CORE (I.E. RECOVERED).
II PROBABLE SOFT ZONE - FAIR EVIDENCE OF ZONE IN CORE, BUT ZONE NOT INTACT.
III POSSIBLE SOFT ZONE - SLIGHT EVIDENCE OF ZONE IN CORE; HOWEVER, APPARENT ROCK TO ROCK CONTACT IN MOST CASES.

ASSIFICATION SYSTEM

ML SILTS, SANDY SILTS, GRAVELLY SILTS OR DIATOMACEOUS SOILS
CL LEAN CLAYS, SANDY CLAYS, OR GRAVELLY CLAYS
OL ORGANIC SILT, OR LEAN ORGANIC CLAYS
MH MICACEOUS SILTS, DIATOMACEOUS SOILS OR PLASTIC SILTS
CH FAT CLAYS
OH FAT ORGANIC CLAYS
PT PEAT, HUMUS, AND OTHER ORGANIC SWAMP SOILS

ANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

System	Group	Formation	Thickness	Symbol	Description
SILURIAN		OATKA	23'	Sbo	<u>DOLOMITE:</u> **THIN-BEDDED; ARGILLACEOUS, GYPSIFEROUS, SHALE BEDS THROUGHOUT; SOFT TO MODERATELY-HARD; DENSE;** LIGHT-BROWN TO DARK-GRAY.
	SALINA	CAMILLUS	400'	Sc	<u>SHALE:</u> THIN-BEDDED TO MASSIVE; GYPSIFEROUS; SOFT TO MODERATELY-HARD; GRAY TO BROWNISH-GRAY.
	LOCKPORT	LOCKPORT	+140	Sl	<u>DOLOMITE AND DOLOMITE LIMESTONE:</u> THIN-BEDDED TO MASSIVE; ARGILLACEOUS TO SHALY, OCCASIONAL CALCITE AND GYPSU PARTINGS, OCCASIONAL CARBONACEOUS AND SHALY PARTINGS, CHERT NODULES; MODERATELY-HARD TO HARD; DENSE TO FINE-C TALLINE; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) THAT ARE OCCASIONALLY STAINED AND WIDENED BY SOLUTION ACTION, OCCASIONAL MINERALIZED SOLUTION PITS AND VUGS; VARIOUS SHADES OF GRAY.
	CLINTON	ROCHESTER	62'	Sr	<u>SHALE:</u> LAMINATED TO BLOCKY; UPPER IS SLIGHTLY CALCAREOUS WITH OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE. LOWE IS SLIGHTLY CALCAREOUS WITH BANDS AND THIN BEDS OF LIMESTONE, OCCASIONAL GYPSUM PARTINGS ALONG LAMINAE; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN); DARK-GRAY.
		IRONDEQUOIT	18'	Si	<u>LIMESTONE:</u> MEDIUM-BEDDED TO MASSIVE; OCCASIONAL SHALE PARTINGS; MODERATELY-HARD TO HARD; DENSE TO CRYSTALLI CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) SOME WIDENED BY SOLUTION ACTION, OCCASIONAL VUGS; LIGHT-TO MEDIUM-GRAY.
		REYNALES	5'	Sre	<u>LIMESTONE:</u> THIN-BEDDED; ARGILLACEOUS, SLIGHTLY-CALCAREOUS; MODERATELY-HARD TO HARD; FINE-CRYSTALLINE TO CRYSTALLINE; GRAY.
		NEAHGA	6'	Sn	<u>SHALE:</u> PLATY; SLIGHTLY-SILTY, SLIGHTLY-CALCAREOUS, WAXY, OCCASIONAL GYPSUM PARTINGS ALONG BEDDING PLANES; SO CONTAINS JOINTS AND FRACTURES (TIGHT TO OPEN) OCCASIONALLY STAINED AND OCCASIONALLY FILLED WITH PYRITE; GREENISH-GRAY.
	MEDINA	THOROLD	6'	St	<u>SANDSTONE TO SILTSTONE:</u> MEDIUM-BEDDED TO MASSIVE; QUARTZITIC WITH QUARTZ GRAINS (ANGULAR TO SUB-ANGULAR) CEMENTED WITH SILICA, OCCASIONAL SHALE AND GYPSUM PARTINGS; HARD; FINE-GRAINED; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE STAINED, SOME SLIGHTLY OPEN; LIGHT-GRAY.
		GRIMSBY	50'	Sg	<u>SILTSTONE AND SANDSTONE:</u> INTERBEDDED WITH SHALE AND SANDSTONE; MODERATELY-HARD TO HARD; FINE-TO MEDIUM-GRAINE CONTAINS OCCASIONAL JOINTS AND FRACTURES (TIGHT TO OPEN); PINK, WHITE, OR PALE-GREEN, MOTTLED SILTSTONE OR SAN WITH RED SHALE AND RED SANDSTONE INTERBEDS.
		POWER GLEN	35'	Sp	<u>SHALE:</u> LAMINATED TO PLATY; ARGILLACEOUS WITH OCCASIONAL THIN CALCAREOUS SILTSTONE BEDS; SLIGHTLY-SOFT TO MODERATELY-HARD; CONTAINS OCCASIONAL JOINTS AND FRACTURES THAT ARE OCCASIONALLY SLIGHTLY STAINED AND OCCASIONAL OPEN; GRAYISH-GREEN WITH LIGHT-TO MEDIUM-GRAY SILTSTONE.
		WHIRLPOOL	20'	Sw	<u>SANDSTONE:</u> MEDIUM-BEDDED TO MASSIVE; CROSS-BEDDED; QUARTZITIC, OCCASIONAL INCLUSIONS OF GREEN SHALE; HARD; WELL CEMENTED WITH SILICA; MEDIUM-TO COARSE GRAINED (WELL-ROUNDED, FROSTED, QUARTZ GRAINS); OCCASIONAL JOINTS AND FRACTURES; LIGHT-GRAY TO WHITE. UNCONFOR
ORDOVICIAN		QUEENSTON	+1200'	Oq	<u>SHALE:</u> (TECHNICALLY CLASSIFIED AS A CLAYSTONE), MASSIVE; CALCAREOUS; SOFT TO MODERATELY-HARD; OCCASIONAL HIGH A LOW ANGLE JOINT SOME HEALED WITH GYPSUM; WEATHERS READILY TO BLOCKS UPON EXPOSURE TO THE ATMOSPHERE; PURPLE-RED WITH GREEN OR GRAY MOTTLING.

JOINT CLASSIFICATION AND DEFINITIONS

HORIZONTAL JOINT	0° TO $\pm10^\circ$ FROM THE HORIZONTAL
LOW ANGLE JOINT	$\pm10^\circ$ TO $\pm45^\circ$ FROM THE HORIZONTAL
HIGH ANGLE JOINT	$\pm45^\circ$ TO $\pm85^\circ$ FROM THE HORIZONTAL
VERTICAL JOINT	$\pm85^\circ$ TO $\pm90^\circ$ FROM THE HORIZONTAL

D; DENSE;

LCITE AND GYPSUM
ENSE TO FINE-CRYS-
ED BY SOLUTION

LAMINAE. LOWER
LAMINAE;

E TO CRYSTALLINE;
LIGHT-TO

TALLINE TO

ING PLANES; SOFT;
PYRITE;

B-ANGULAR)
ONAL JOINTS

TO MEDIUM-GRAINED,
SILTSTONE OR SANDSTONE

TLY-SOFT TO
D AND OCCASIONALLY

SHALE; HARD;
ASIONAL JOINTS

UNCONFORMITY

CASIONAL HIGH AND
HERE; PURPLE-

cong	conglomerate	pla	platy
crm	crumbly	pln	plane
d	dense	ptg(s)	parting,partings
dk	dark	*qtz	quartzite,quartz
dmp	damp	rnd	round,rounded
*dol	dolomite,dolomitic	sat	saturated
ext	extremely	scat	scattered
f	fine,finely	sd	sand,sandy
fe	iron	*sh	shale,shaly
fld	filled	si	silt,silty
fm	firm	*sis	siltstone
fos	fossil,fossilferous	sl	slightly
frac(s)	fractures	slcs	siliceous
frag	fragments	slks	slickensides
fri	friable	so	soft
fsl	fissile	ss	sandstone
gen	generally	st	stiained, staining
gr	grain	stf	stiff
gra	gradation	v	very
grn	green	var	variegated
grv	gravel,gravelly	vert	vertical
gry	gray	vgy	vuggy
*gyp	gypsum	w	water
ha	high angle	w/	with
*hal	halite	wea	weathered
hd	hard	wht	white
hor	horizontal	x-bdd	cross bedded
inbd	interbedded	xin	crystalline
incl	inclusions	y	yellow
irr	irregular	*WHEN USED AS LOG SYMBOL	
jt	joint	FIRST LETTER IS CAPITALIZED	

A
U
D
C
R
P
SI

I KNOWN SOFT ZONE -

II PROBABLE SOFT ZONE

III POSSIBLE SOFT ZONE

UNIFIED SOIL CLASSIFICATION SYSTEM

GW	GRAVEL OR SANDY GRAVEL, WELL GRADED	ML	SILTS, SANDY SILTS, GRAVELLY SILTS O
GP	GRAVEL OR SANDY GRAVEL, POORLY GRADED	CL	LEAN CLAYS, SANDY CLAYS, OR GRAVELLY
GM	SILTY GRAVEL,OR SILTY SANDY GRAVEL	OL	ORGANIC SILT, OR LEAN ORGANIC CLAYS
GC	CLAYEY GRAVEL OR CLAYEY SANDY GRAVEL	MH	MICACEOUS SILTS, DIATOMACEOUS SOILS O
SW	SAND OR GRAVELLY SAND, WELL GRADED	CH	FAT CLAYS
SP	SAND OR GRAVELLY SAND, POORLY GRADED	OH	FAT ORGANIC CLAYS
SM	SILTY SAND OR SILTY GRAVELLY SAND	PT	PEAT, HUMUS, AND OTHER ORGANIC SWAMP
SC	CLAYEY SAND OR CLAYEY GRAVELLY SAND		

NOTE:

DUAL CLASSIFICATIONS, WHERE USED, ARE IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATIO

TERMS FOR STRENGTH OF SOILS AND HARDNESS OF BEDROCK

SOILS

ESTIMATED STRENGTHS

CONSISTANCY	UNCONFINED COMPRESSIVE STRENGTH (TONS PER SQUARE FOOT)
VERY SOFT	0.25
SOFT	0.25-0.5
MEDIUM	0.5-1.0
STIFF	1.0-2.0
VERY STIFF	2.0-4.0
HARD	4.0

BEDROCK

SCALE OF HARDNESS

VERY SOFT OR PLASTIC	CAN BE INDENTED EASILY WITH THUMB.
SOFT	CAN BE SCRATCHED WITH FINGERNAIL.
MODERATELY HARD	CAN BE SCRATCHED EASILY WITH KNIFE. CANNOT BE SCRATCHED WITH FINGERNAIL.
HARD	DIFFICULT TO SCRATCH WITH KNIFE.
VERY HARD	CANNOT BE SCRATCHED WITH KNIFE.

LAKE ERIE

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TYPE OF EXPLORATION
CODE DESIGNATION

A - AUGER HOLE - HAND OR POWER A
U - UNDISTURBED SAMPLE HOLE
D - DRIVE SAMPLE HOLE
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II PROBABLE SOFT ZONE - FAIR EVIDENCE OF ZONE IN CORE, BUT ZONE NOT INTACT.

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CL LEAN CLAYS, SANDY CLAYS, OR GRAVELLY CLAYS

OL ORGANIC SILT, OR LEAN ORGANIC CLAYS

MH MICACEOUS SILTS, DIATOMACEOUS SOILS OR PLASTIC SILTS

CH FAT CLAYS

OH FAT ORGANIC CLAYS

PT PEAT, HUMUS, AND OTHER ORGANIC SWAMP SOILS

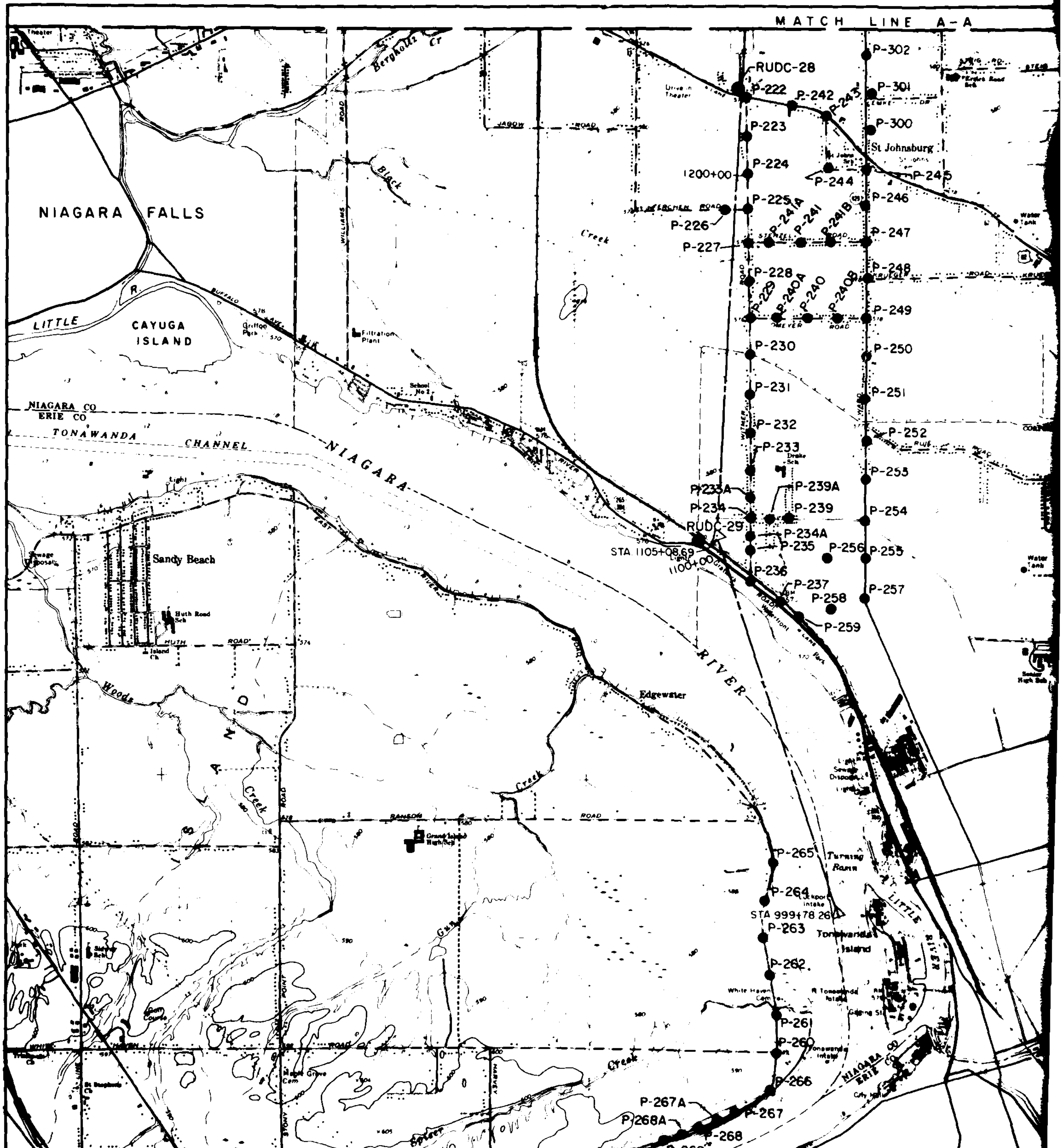
CCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM.

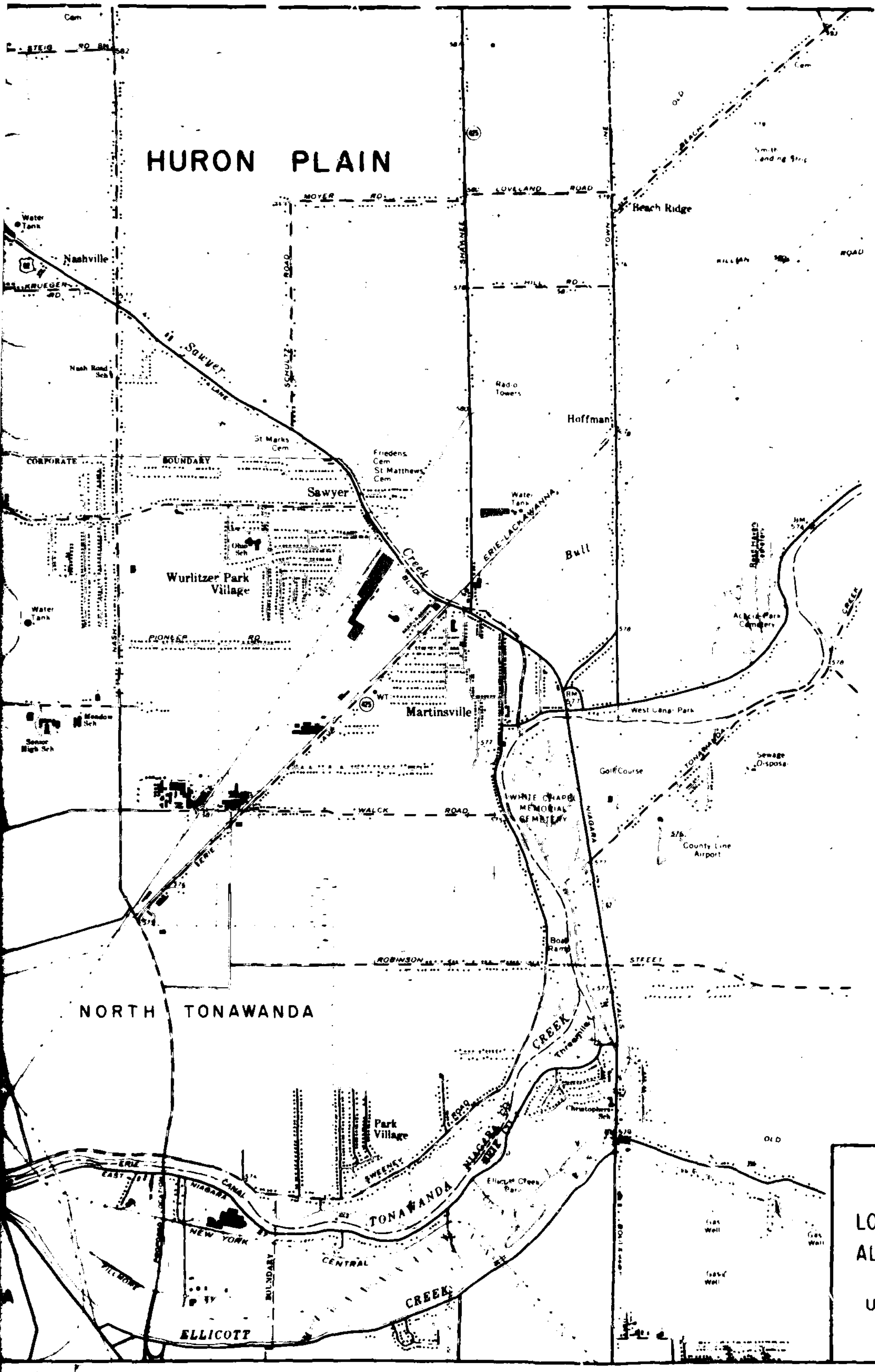
LAKE ERIE-LAKE ONTARIO WATERWAY

LEGEND FOR GEOLOGIC INVESTIGATIONS

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973


MATCH LINE A-A
RUDC-28
P-222
P-242
P-243
P-302
P-301
P-300
St Johnsburg
P-223
P-224
1200+00
P-244
P-245
P-225
P-246
P-226
P-241A
P-241
P-241B
P-227
P-247
P-228
P-248
P-229
P-240A
P-240
P-240B
P-249
P-230
P-250
P-231
P-251
P-232
P-252
P-233
P-233A
P-239A
P-234
P-239
P-253
P-254
RUDC-29
P-234A
P-235
P-256
P-255
STA 1105+08.69
1100+00
P-236
P-237
P-258
P-257
P-259
NIAGARA FALLS
LITTLE R.
CAYUGA ISLAND
NIAGARA CO
ERIE CO
TONAWANDA CHANNEL
NIAGARA RIVER
Bergholtz Cr
Black Creek
Filtration Plant
School No 2
Drake Sch
Sandy Beach
Huth Road Sch
Woods Creek
Edgewater
Grand Island High Sch
Gun Creek
P-265
Turning Basin
P-264
STA 999+78.26
P-263
Tonawanda Island
P-262
White Haven Cem
P-261
P-260
Maple Grove Cem
Spicer Creek
P-266
P-267A
P-267
P-268A
P-268
P-269
LITTLE RIVER
TONAWANDA



SHEET INDEX

SEE PLATE B5
SEE PLATE B4
SEE PLATE B3
THIS PLATE B2

NOTES:

For profiles of locks see plates B20, B21, B22, B23 and B24.

For legend of borings see plate B1.

A — Location of profile — A

SCALE OF FEET

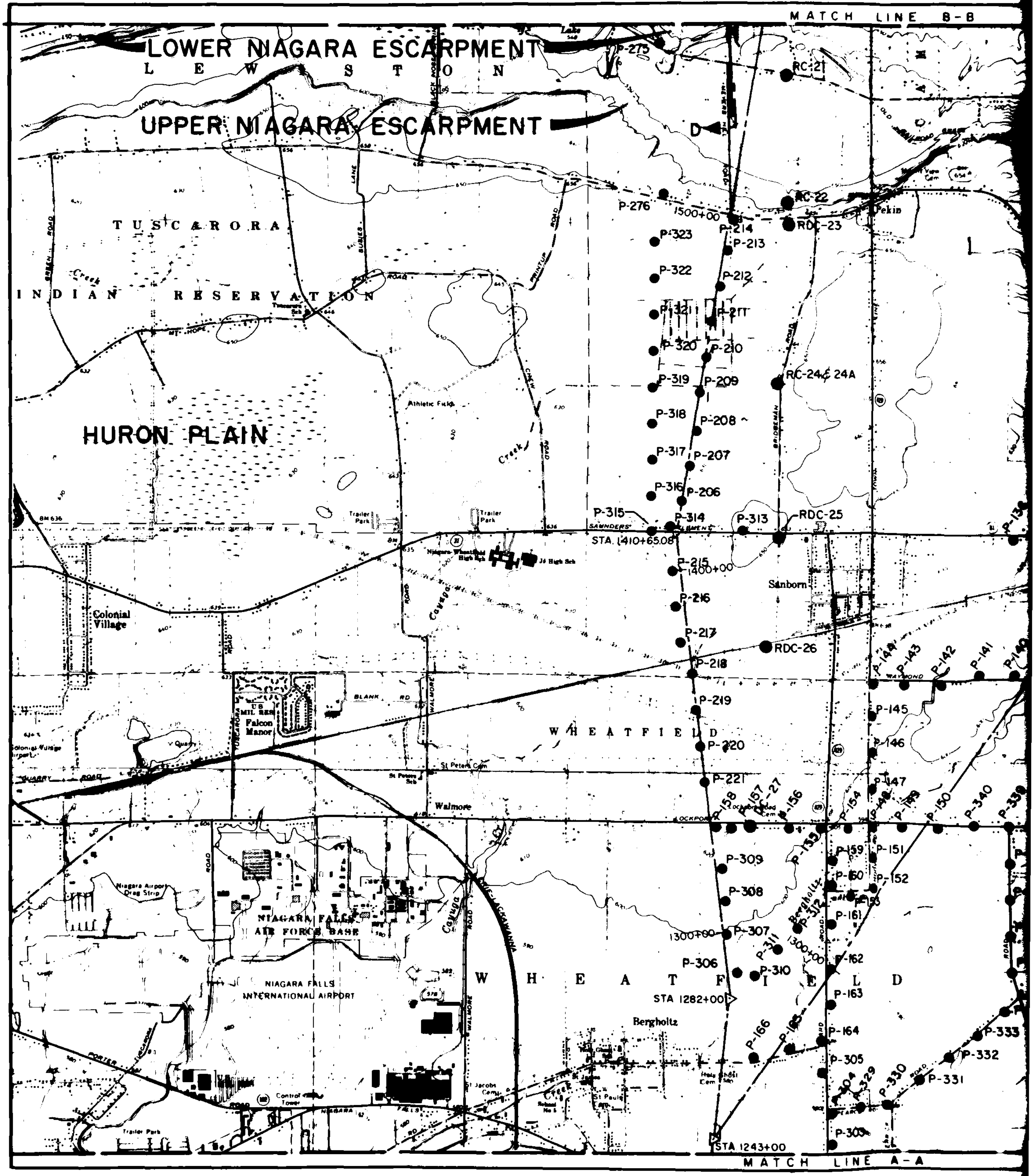
2000 1000 0 2000 4000

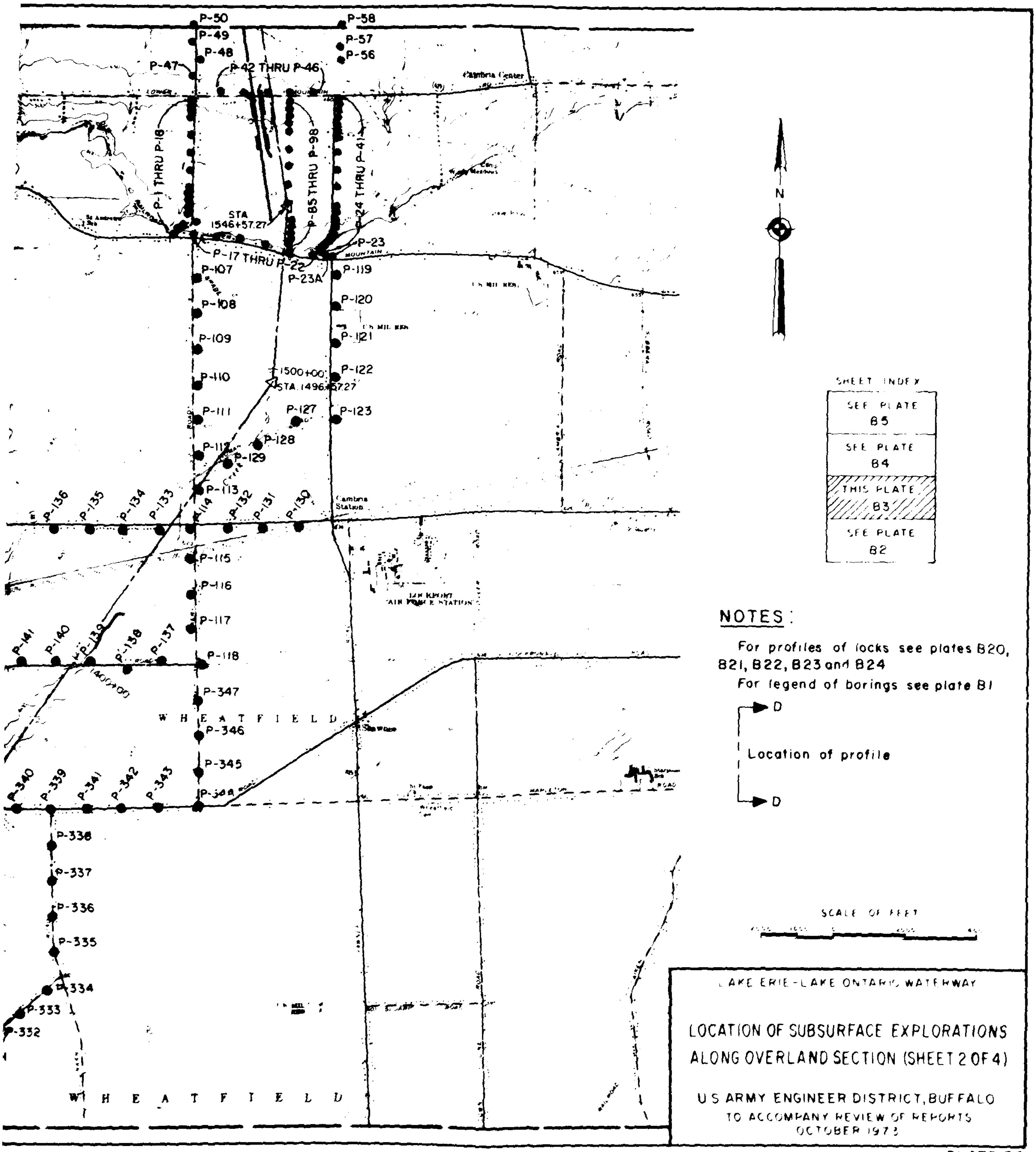
LAKE ERIE-LAKE ONTARIO WATERWAY

LOCATION OF SUBSURFACE EXPLORATIONS ALONG OVERLAND SECTION (SHEET 1 OF 4)

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973


MATCH LINE B-B
LOWER NIAGARA ESCARPMENT
L E W I S T O N
UPPER NIAGARA ESCARPMENT
T U S C A R O R A
I N D I A N R E S E R V A T I O N
HURON PLAIN
Colonial Village
Falcon Manor
W H E A T F I E L D
Walmore
NIAGARA FALLS AIR FORCE BASE
NIAGARA FALLS INTERNATIONAL AIRPORT
Bergholtz
Sanborn
Pekin
P-275
RC-21
RC-22
RDC-23
P-276
1500+00
P-214
P-213
P-323
P-322
P-212
P-321
P-211
P-320
P-210
RC-24 & 24A
P-319
P-209
P-318
P-208
P-317
P-207
P-316
P-206
P-315
P-314
P-313
RDC-25
STA. 1410+65.08
P-215
1400+00
P-216
P-217
RDC-26
P-218
P-219
P-220
P-221
P-144
P-143
P-142
P-141
P-140
P-145
P-146
P-147
P-148
P-149
P-150
P-340
P-339
P-158
P-157
P-156
P-154
P-159
P-151
P-160
P-152
P-309
P-308
P-161
P-307
1300+00
P-311
P-310
P-306
P-162
STA 1282+00
P-163
P-164
P-166
P-165
P-333
P-332
P-331
P-305
P-330
P-329
P-304
P-303
STA 1243+00
MATCH LINE A-A



NOTES:

For profiles of locks see plates B20, B21, B22, B23 and B24

For legend of borings see plate B1

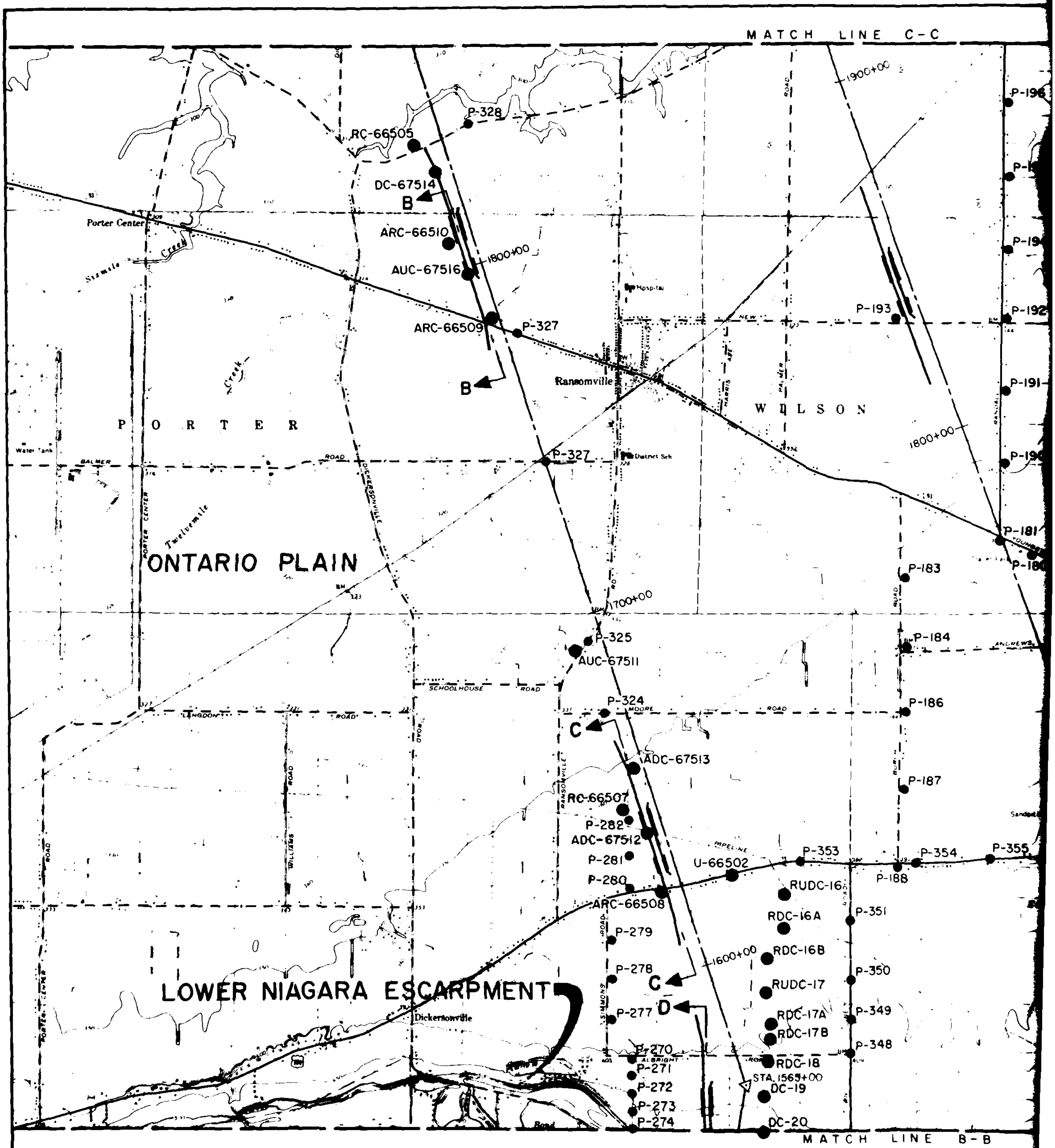
LAKE ERIE-LAKE ONTARIO WATERWAY

LOCATION OF SUBSURFACE EXPLORATIONS ALONG OVERLAND SECTION (SHEET 2 OF 4)

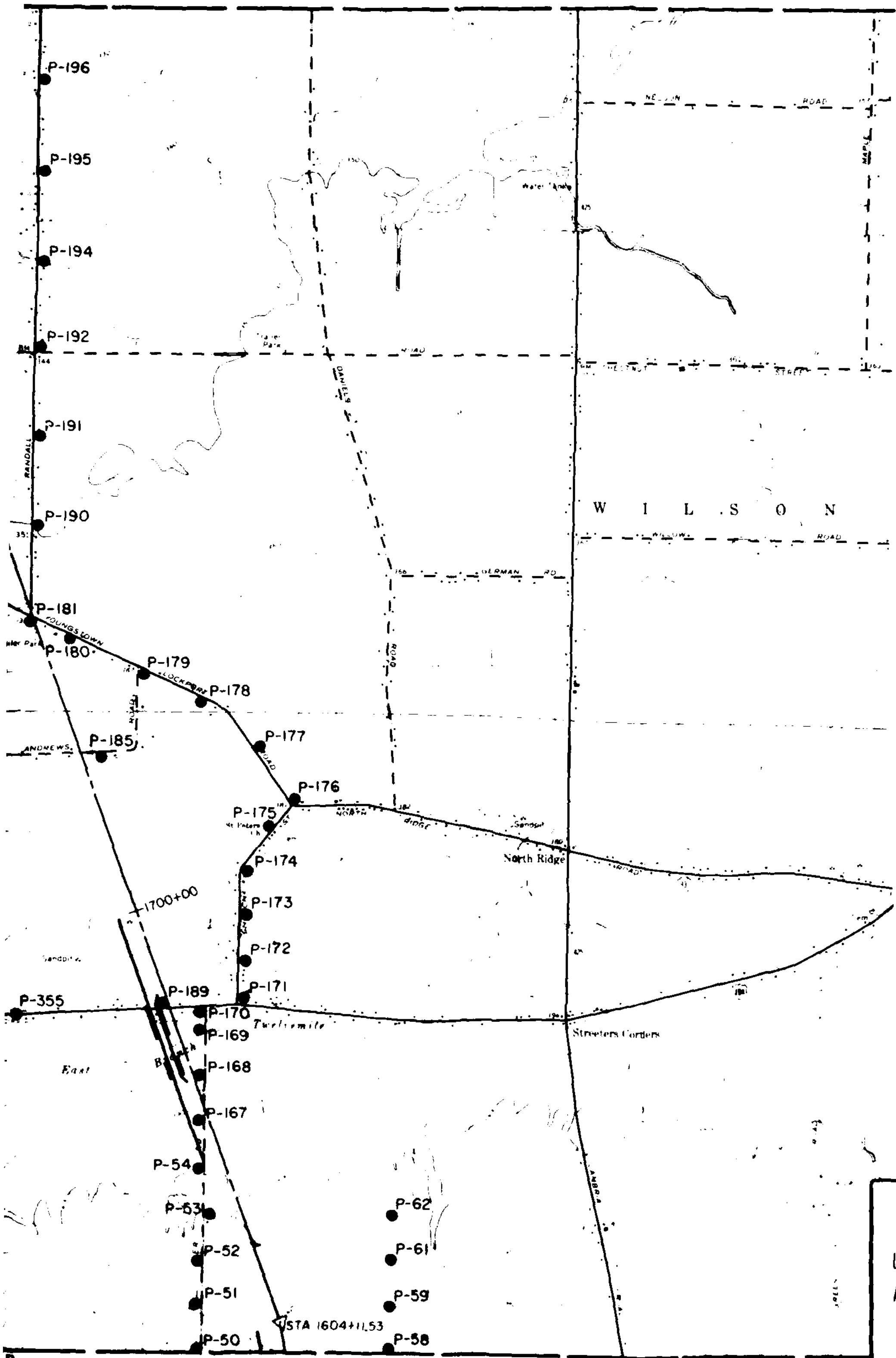
U S ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

PLATE B3



MATCH LINE C-C
1900+00
P-328
RC-66505
DC-67514
B
Porter Center
Sixmile Creek
ARC-66510
1800+00
AUC-67516
Hospital
P-193
ARC-66509
P-327
B
Ransomville
Creek
P O R T E R
W I L S O N
1800+00
Water Tank
BALMER
ROAD
DICKERSONVILLE
P-327
District Sch
PORTER CENTER
Twelvemile
ONTARIO PLAIN
1700+00
P-181
P-183
P-184
P-325
AUC-67511
ANDREWS
SCHOOLHOUSE
ROAD
P-324
LANGDON
ROAD
MOORE
ROAD
P-186
C
ADC-67513
P-187
RANSOMVILLE
WILLIAMS
RC-66507
P-282
ADC-67512
PIPELINE
P-353
P-354
P-355
P-281
U-66502
P-188
P-280
RUDC-16
ARC-66508
P-351
RDC-16A
P-279
1600+00
RDC-16B
P-278
P-350
C
RUDC-17
LOWER NIAGARA ESCARPMENT
D
P-277
RDC-17A
P-349
Dickersonville
RDC-17B
P-270
P-348
ALBRIGHT
P-271
RDC-18
STA. 1565+00
P-272
DC-19
P-273
P-274
DC-20
MATCH LINE B-B



SHEET INDEX

SEE PLATE B5
THIS PLATE B4
SEE PLATE B3
SEE PLATE B2

NOTES:

For profiles of locks see plates B20, B21, B22, B23 and B24.

For legend of borings see plate B1.

B — Location of profile — B

SCALE OF FEET

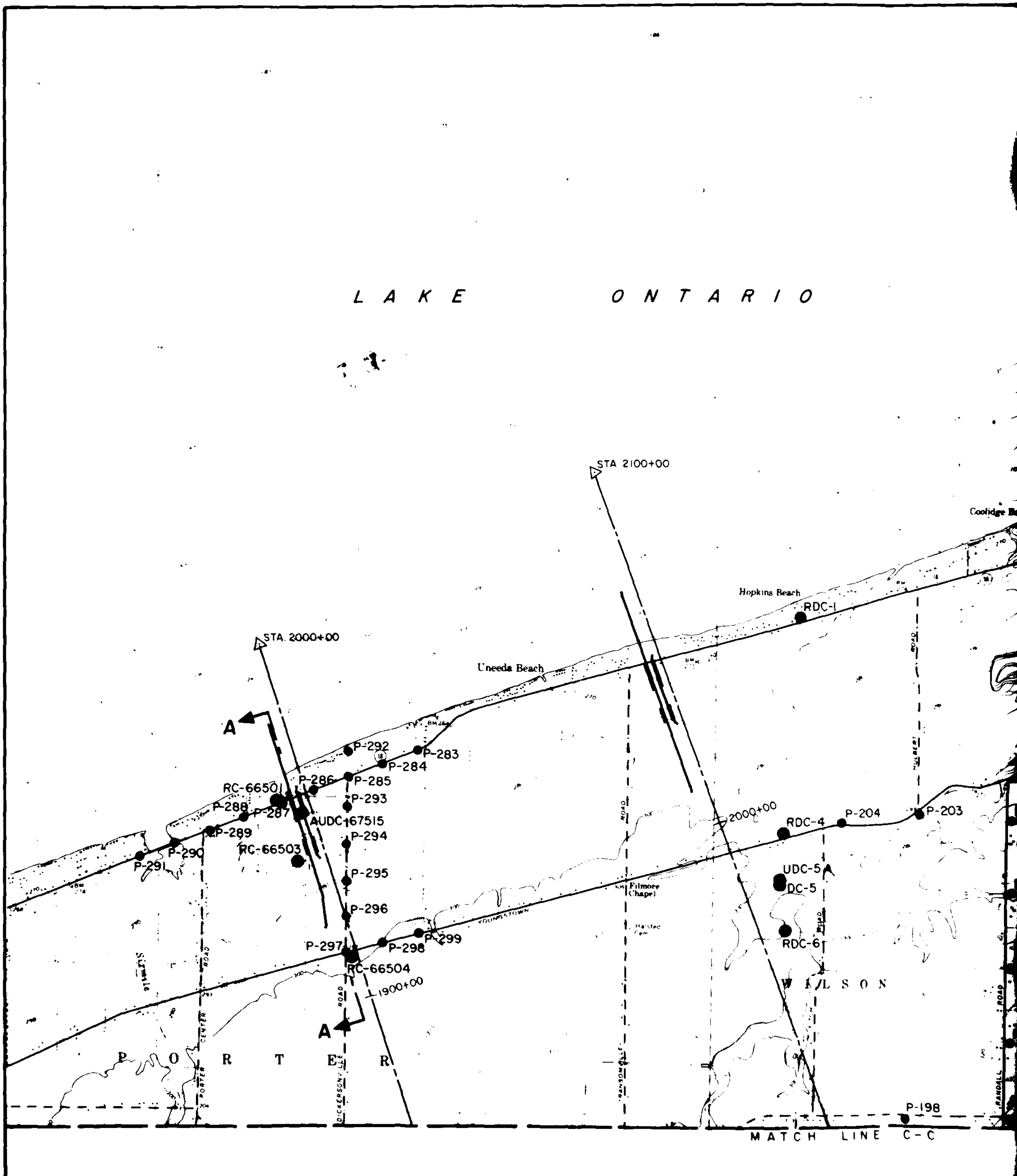
LAKE ERIE-LAKE ONTARIO WATERWAY

LOCATION OF SUBSURFACE EXPLORATIONS ALONG OVERLAND SECTION (SHEET 3 OF 4)

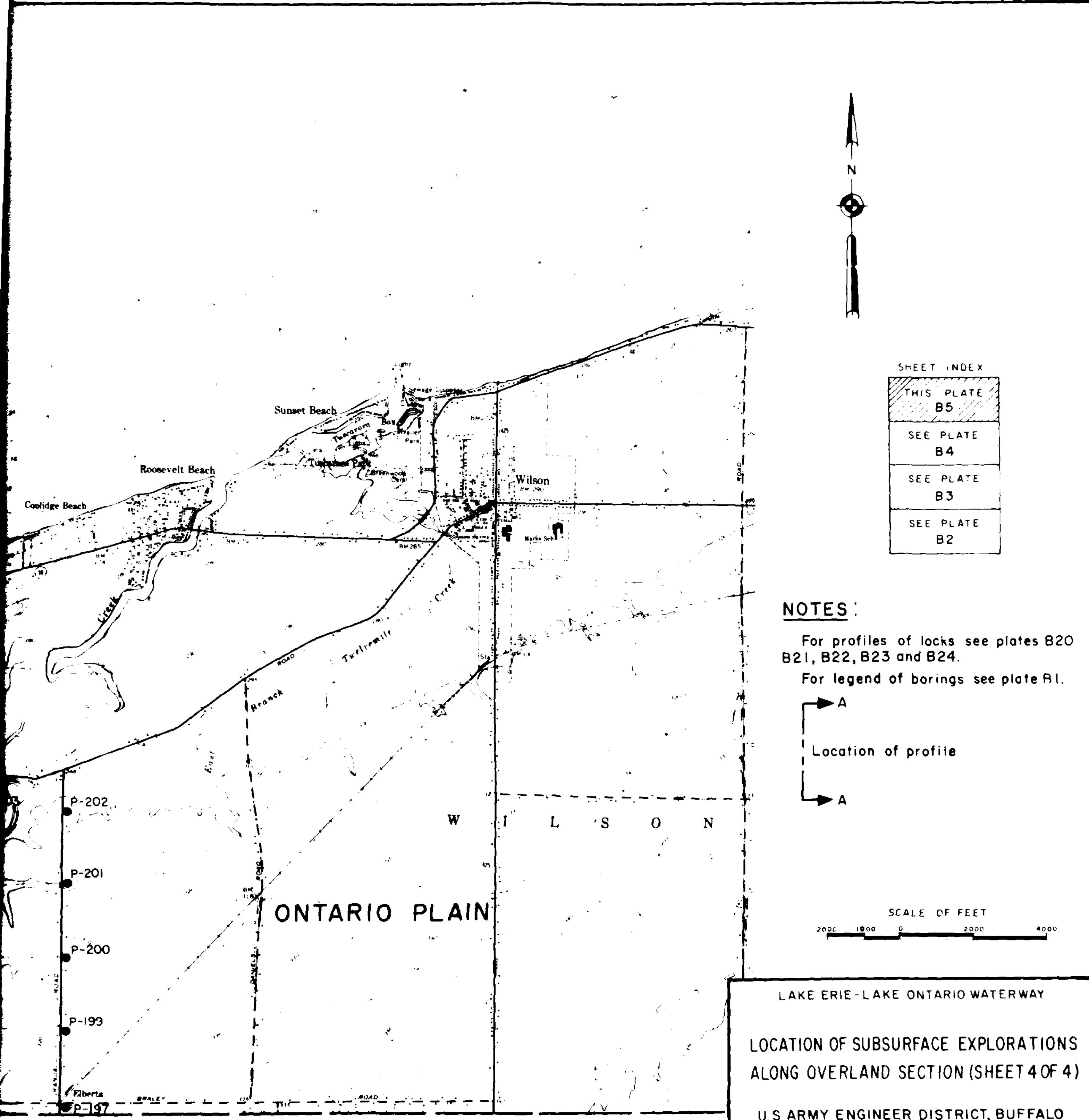
U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

PLATE B4



LAKE ONTARIO
STA 2100+00
STA. 2000+00
Coolidge Be
Hopkins Beach
RDC-1
Uneeda Beach
A
P-292
P-283
P-284
P-285
P-286
RC-66501
P-293
P-288
P-287
AUDC-67515
P-289
P-294
P-290
RC-66503
P-291
P-295
P-296
P-297
P-298
P-299
RC-66504
1900+00
A
2000+00
RDC-4
P-204
P-203
UDC-5
DC-5
RDC-6
Filmore Chapel
YOUNGSTOWN
WILSON
PORTER
P-198
MATCH LINE C-C



LAKE ERIE-LAKE ONTARIO WATERWAY

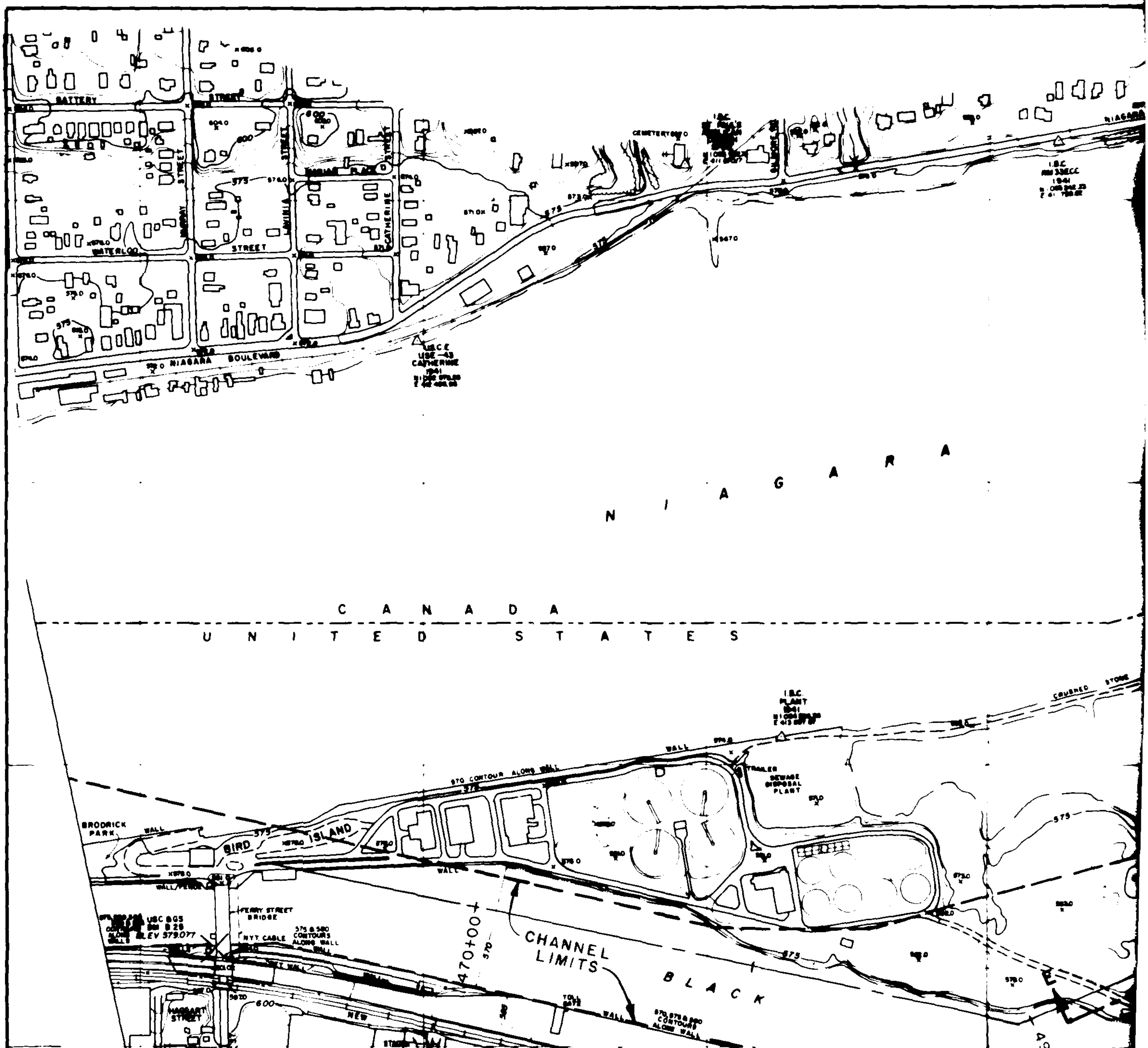
LOCATION OF SUBSURFACE EXPLORATIONS ALONG OVERLAND SECTION (SHEET 4 OF 4)

U.S ARMY ENGINEER DISTRICT, BUFFALO

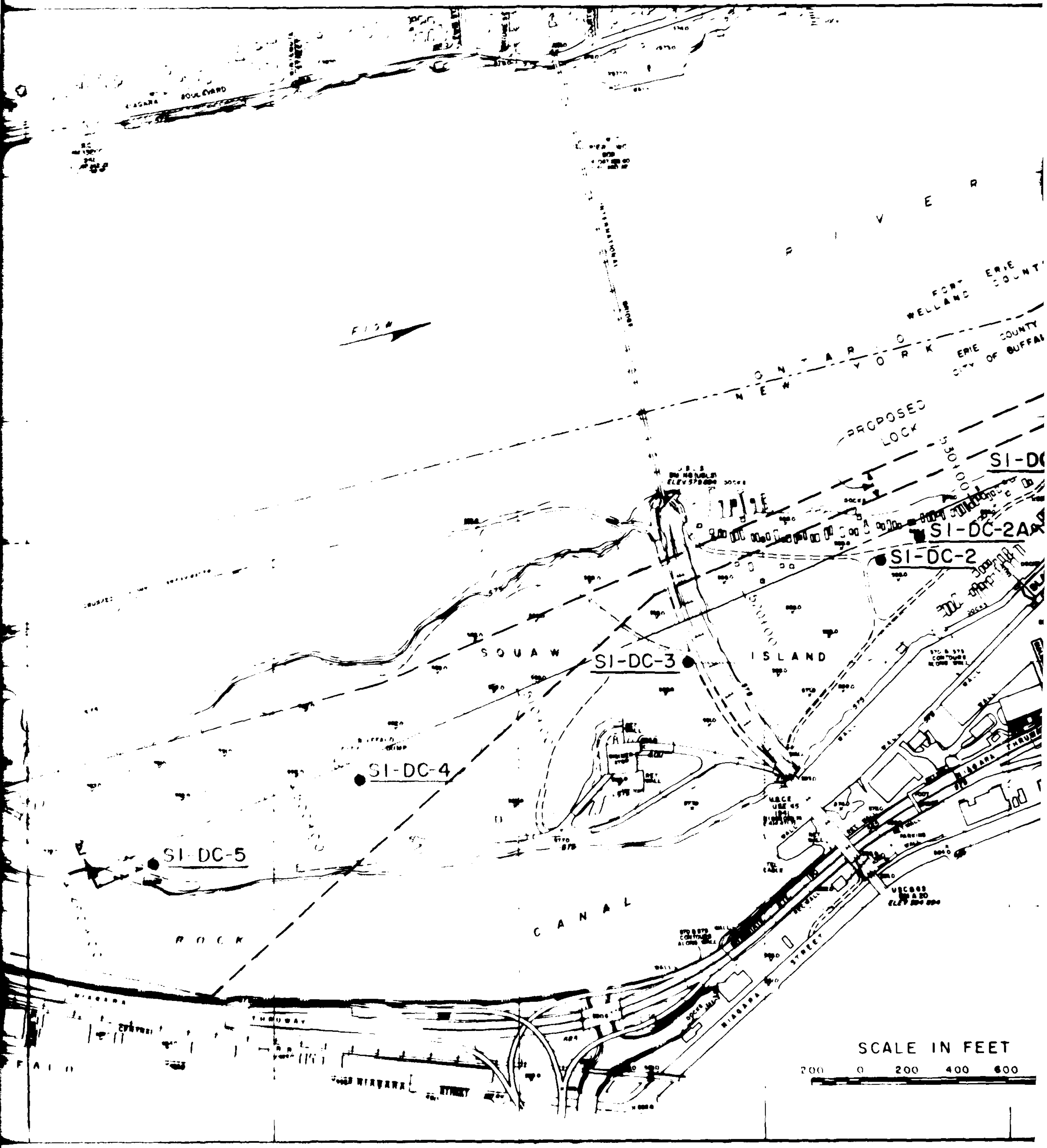
TO ACCOMPANY REVIEW OF REPORTS

OCTOBER 1973

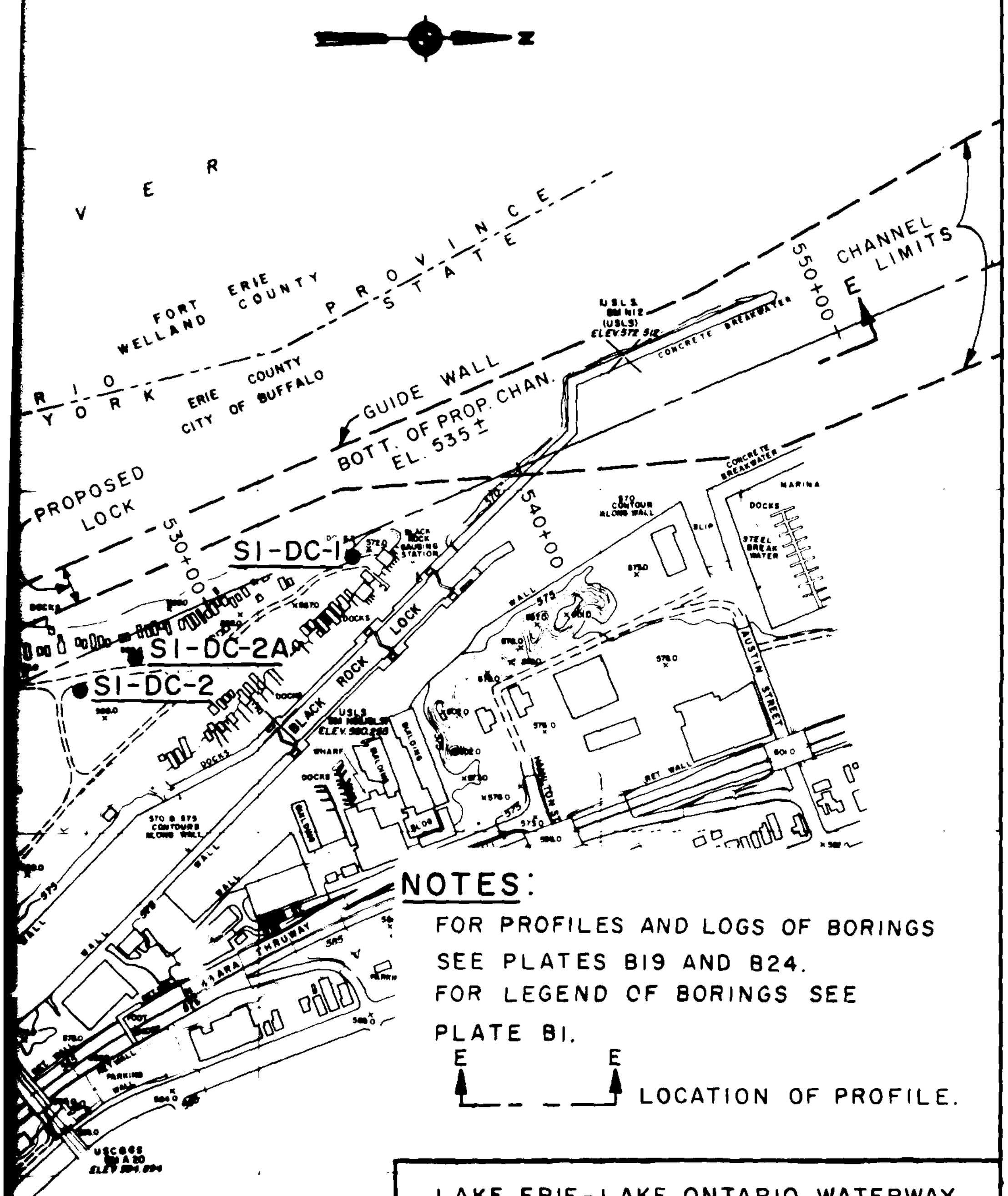
PLATE B5



BATTERY
STREET
WATERLOO
STREET
NIAGARA BOULEVARD
CATHERINE
CEMETERY
N I A G A R A
C A N A D A
U N I T E D S T A T E S
CRUSHED STONE
SEWAGE DISPOSAL PLANT
WALL
570 CONTOUR ALONG WALL
BRODRICK PARK
BIRD ISLAND
FERRY STREET BRIDGE
NYT CABLE
575 & 580 CONTOURS ALONG WALL
470+00
CHANNEL LIMITS
B L A C K
490+00
NEW
YORK
NIAGARA
STREET
HAGGART STREET
RET. WALL
GRACE ST.
TOLL GATE
B U F F A L O



NIAGARA BOULEVARD
RIVER
FLOW
ONTARIO
NEW YORK
FORT ERIE
WELLAND COUNTY
ERIE COUNTY
CITY OF BUFFALO
PROPOSED LOCK
SI-DC-2A
SI-DC-2
SI-DC-3
SI-DC-4
SI-DC-5
SQUAW ISLAND
ROCK CANAL
NIAGARA STREET
SCALE IN FEET
200 0 200 400 600



NOTES:

FOR PROFILES AND LOGS OF BORINGS SEE PLATES B19 AND B24.
FOR LEGEND OF BORINGS SEE PLATE B1.

E ⅃ – – – ⅃ E LOCATION OF PROFILE.

SCALE IN FEET

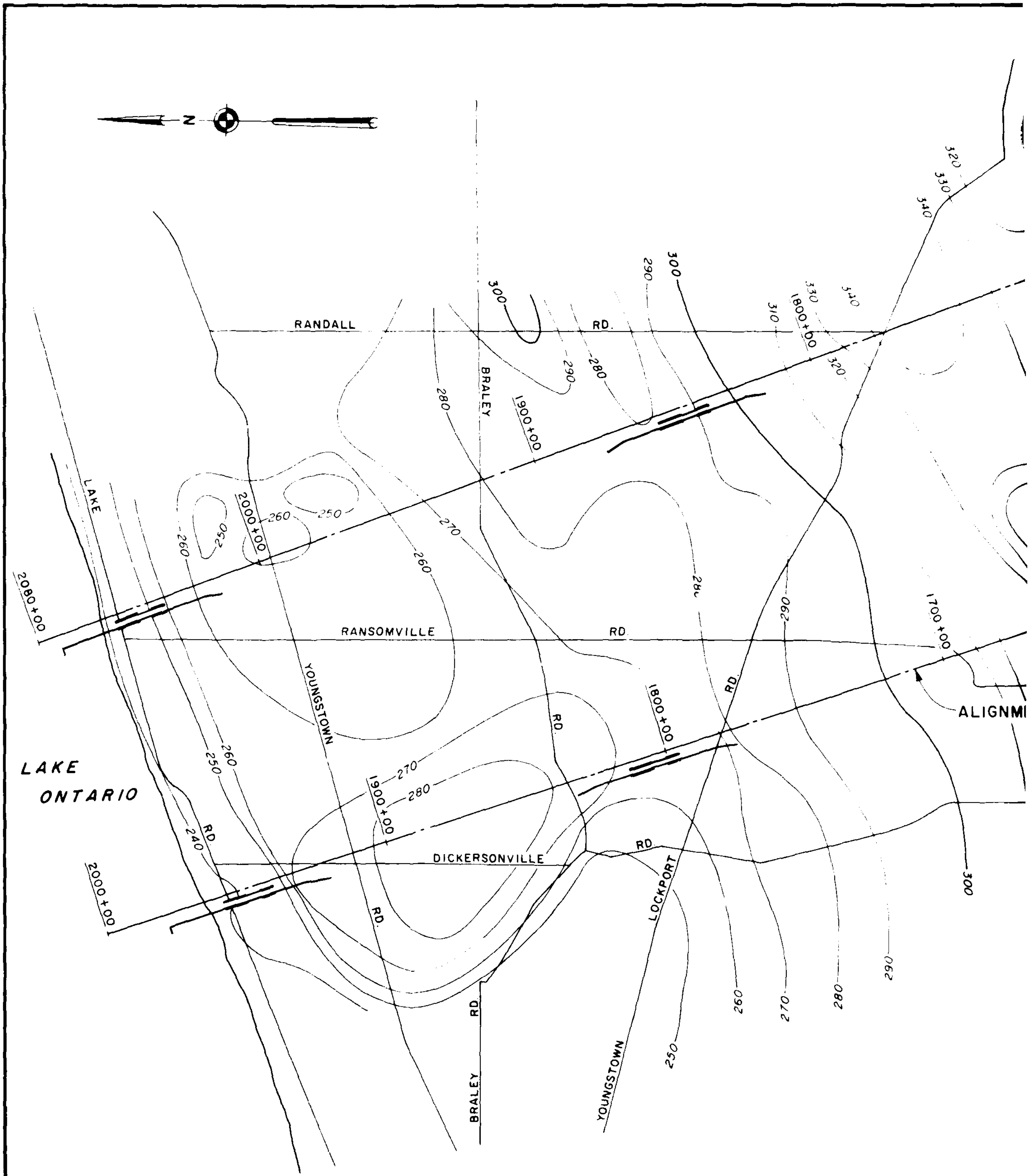
0 200 400 600 800

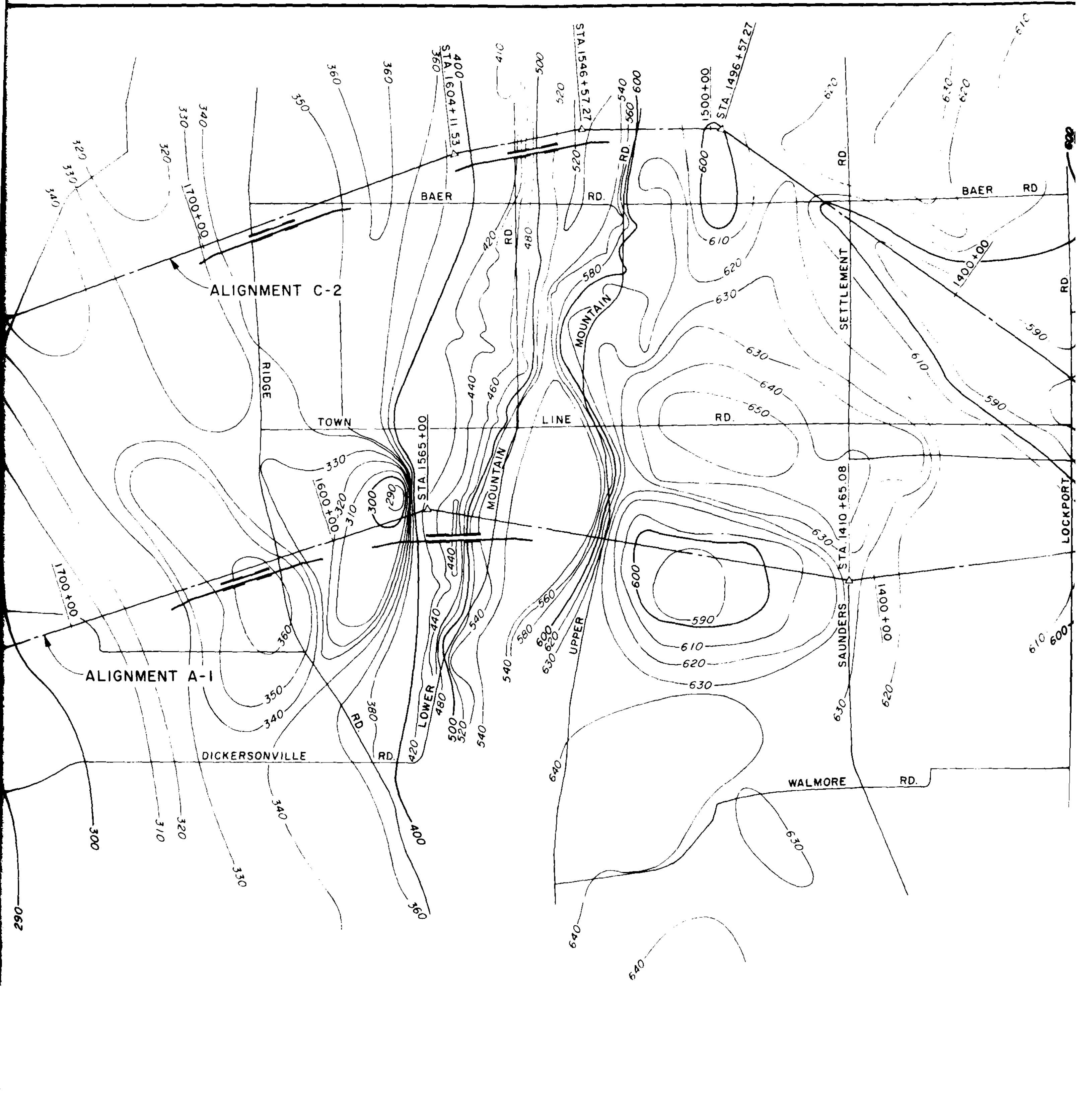
LAKE ERIE-LAKE ONTARIO WATERWAY

LOCATION OF SUBSURFACE EXPLORATIONS AT SQUAW ISLAND

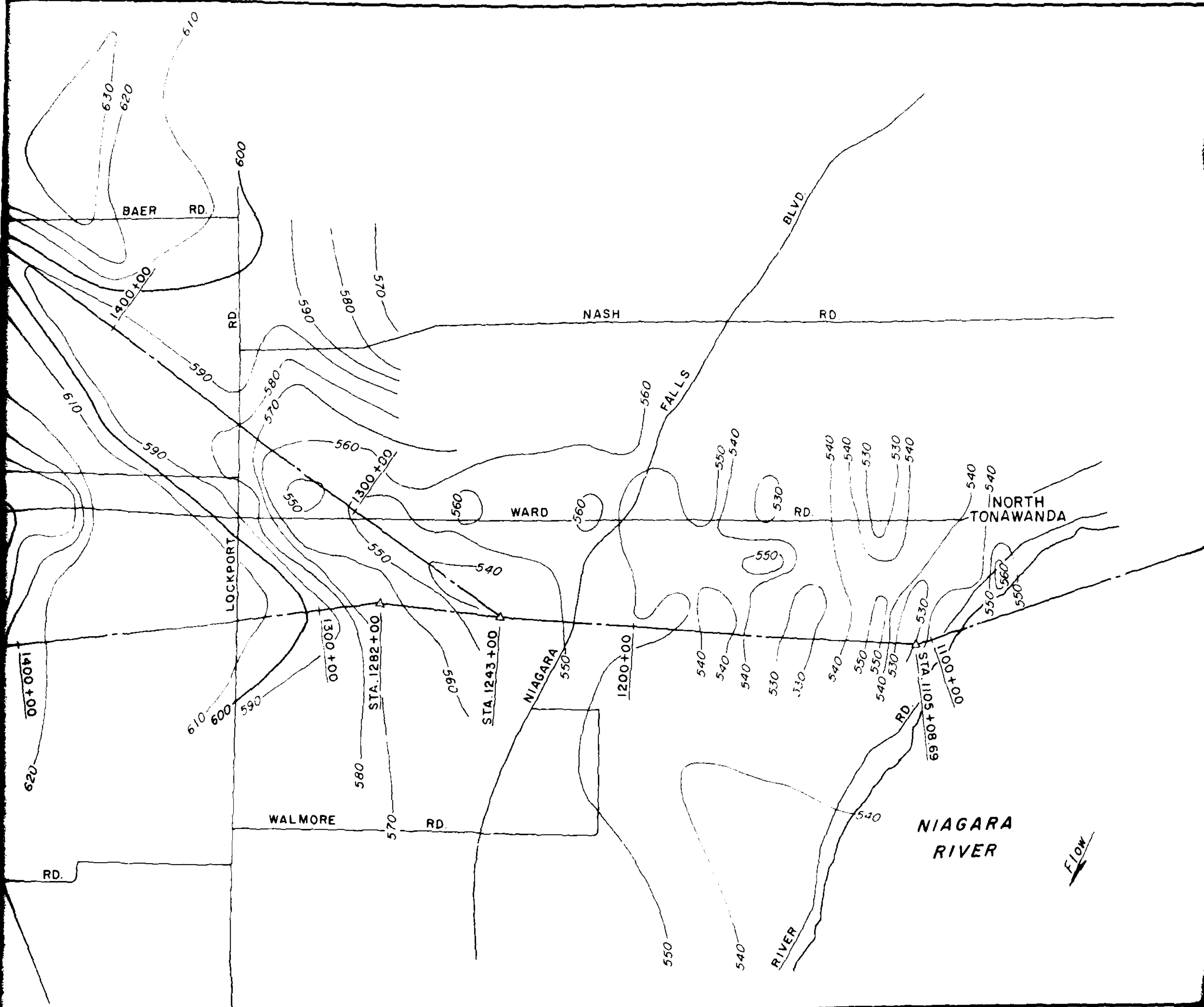
U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973


N
RANDALL RD.
BRALEY
1900+00
1800+00
2000+00
2080+00
LAKE
RANSOMVILLE RD.
YOUNGSTOWN RD.
LAKE ONTARIO
LAKE RD.
1700+00
DICKERSONVILLE RD.
LOCKPORT RD.
BRALEY RD.
YOUNGSTOWN
300
290
280
270
260
250
240
310
320
330
340



ALIGNMENT C-2
ALIGNMENT A-1
STA 1604+11.53
STA 1546+57.27
STA 1496+57.27
1500+00
1700+00
1400+00
STA 1565+00
1600+00
STA 1410+65.08
BAER RD.
BAER RD
TOWN LINE RD.
RIDGE RD.
MOUNTAIN RD.
LOWER MOUNTAIN RD.
UPPER MOUNTAIN RD.
SETTLEMENT RD.
SAUNDERS RD.
LOCKPORT RD
DICKERSONVILLE RD.
WALMORE RD.



NOTES:

TOP OF ROCK CONTOURS ARE BASED MAINLY ON DATA FROM PROBINGS SUPPLEMENTED WITH DATA FROM BOREHOLES DRILLED INTO ROCK.

LOCATIONS OF THE SUBSURFACE EXPLORATIONS ARE SHOWN ON PLATES B2, B3, B4 AND B5.

SCALE IN FEET

2000 0 2000 4000 6000

LAKE ERIE-LAKE ONTARIO WATE

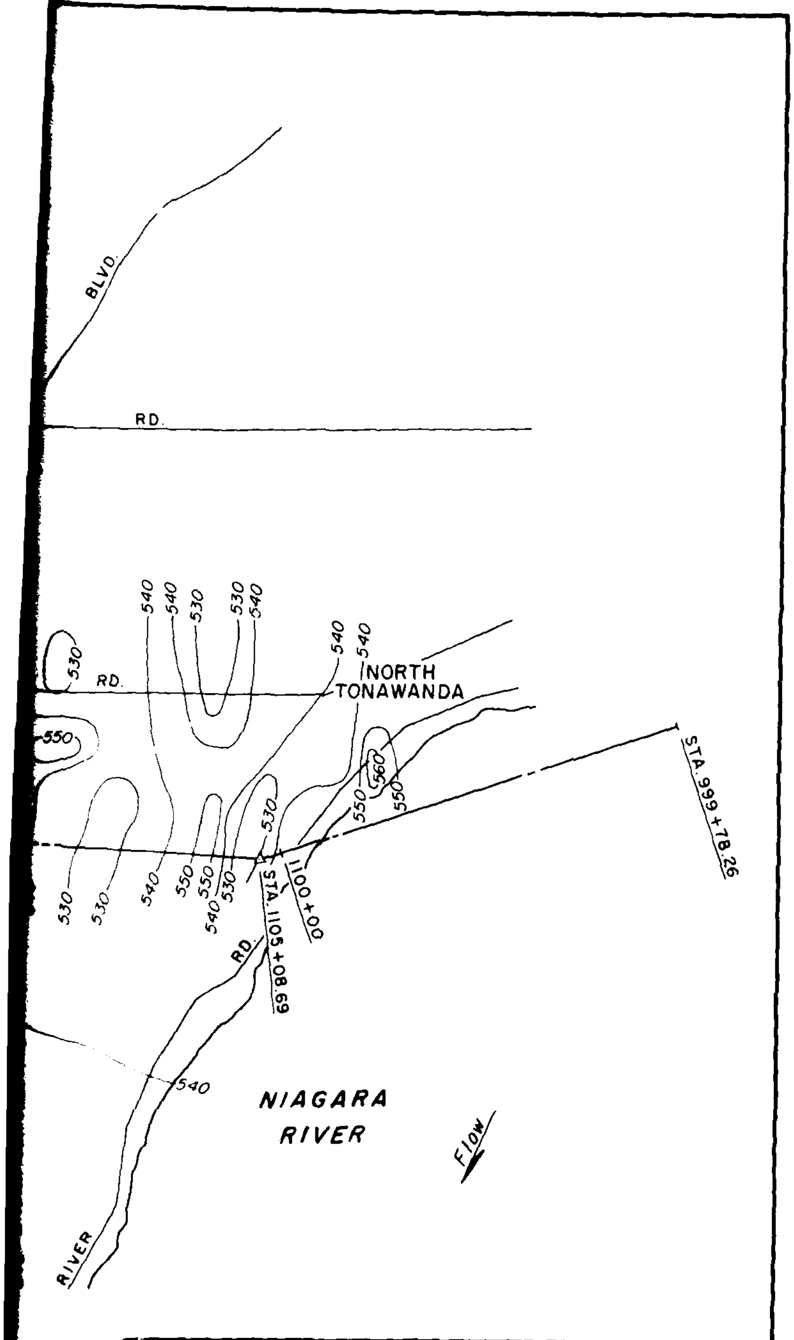
ROCK CONTOUR MAP

U S ARMY ENGINEER DISTRICT, B

TO ACCOMPANY REVIEW OF REPORTS

OCTOBER 1973

P



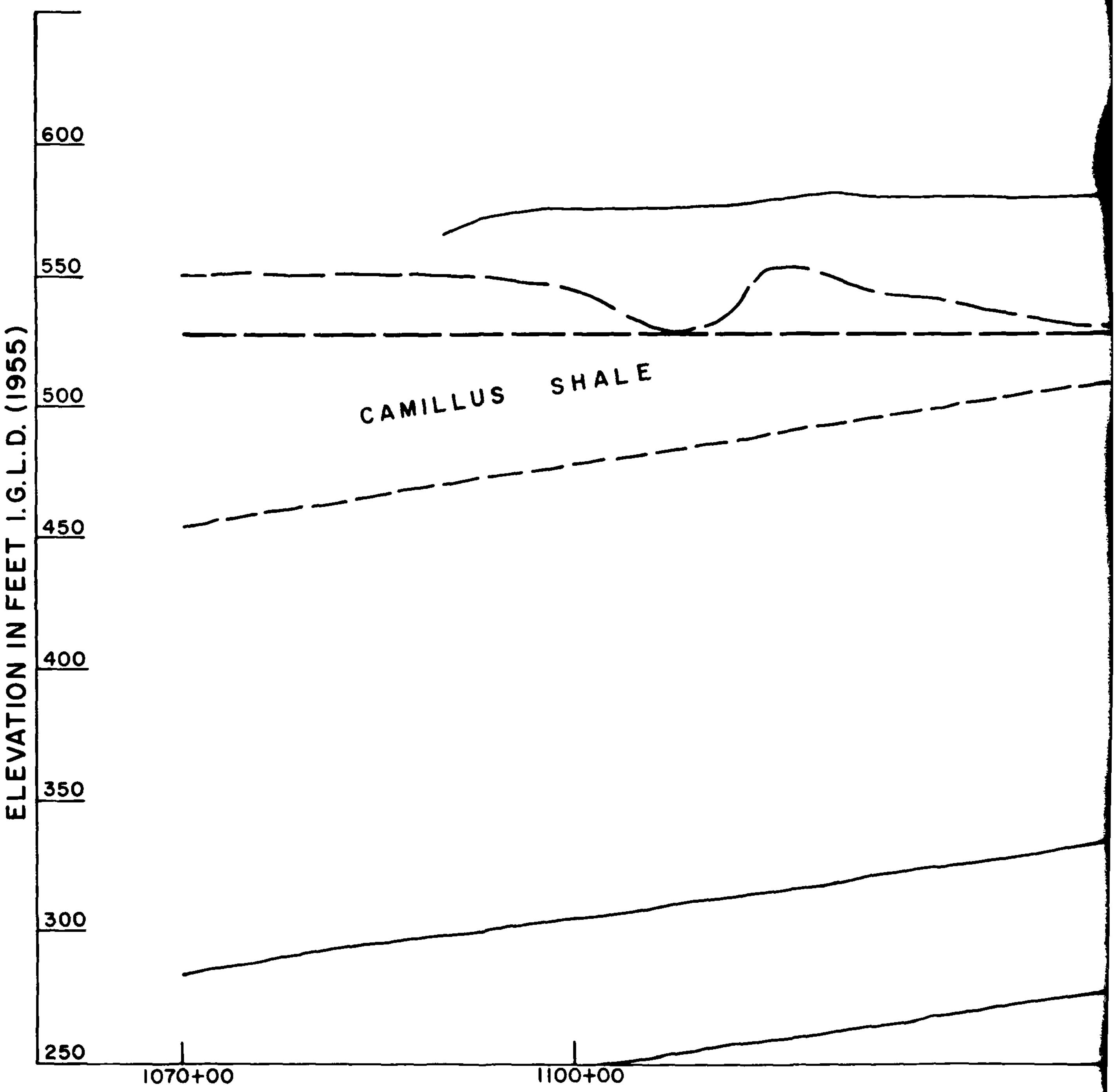
HOLES

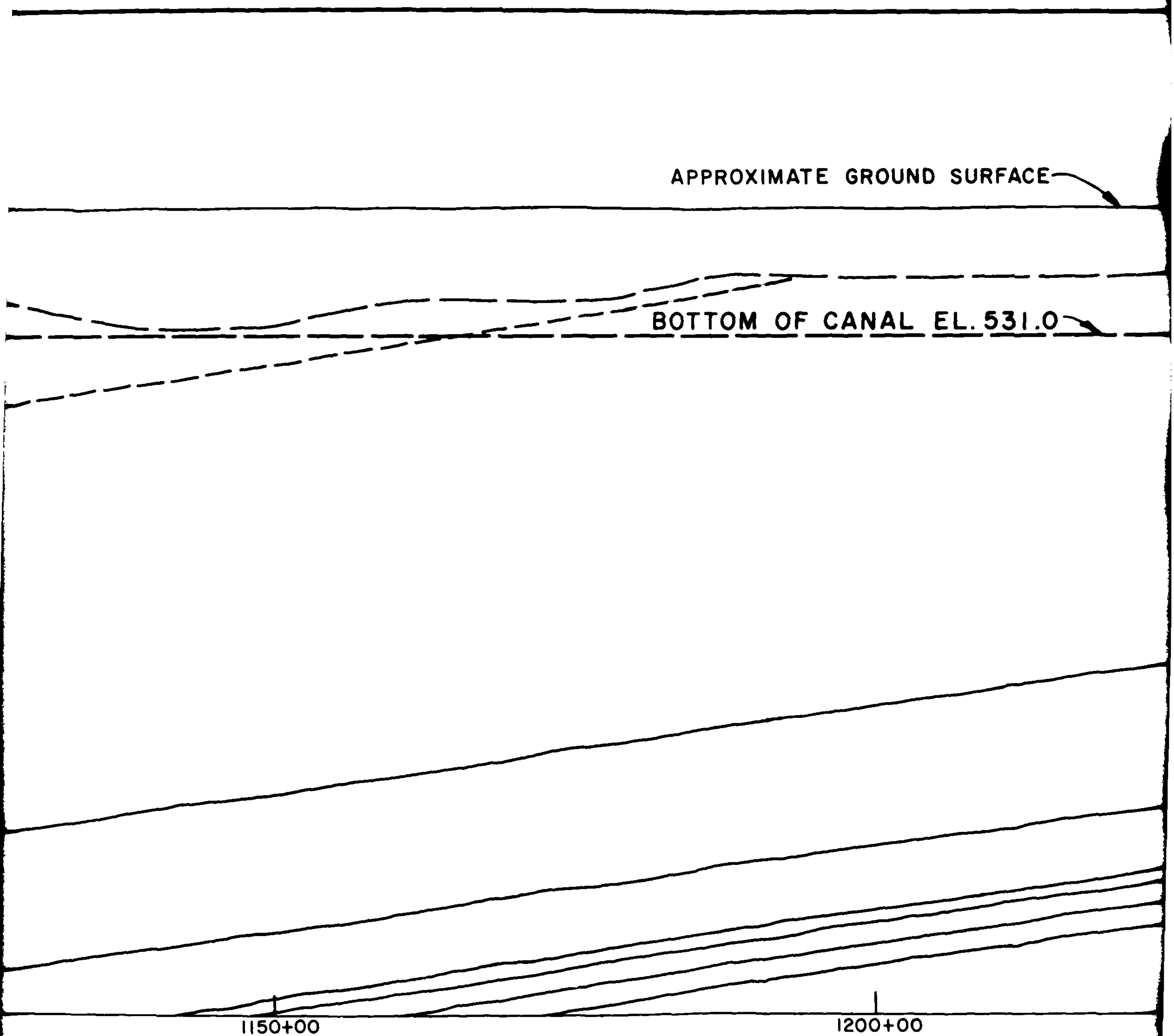
LAKE ERIE-LAKE ONTARIO WATERWAY

ROCK CONTOUR MAP

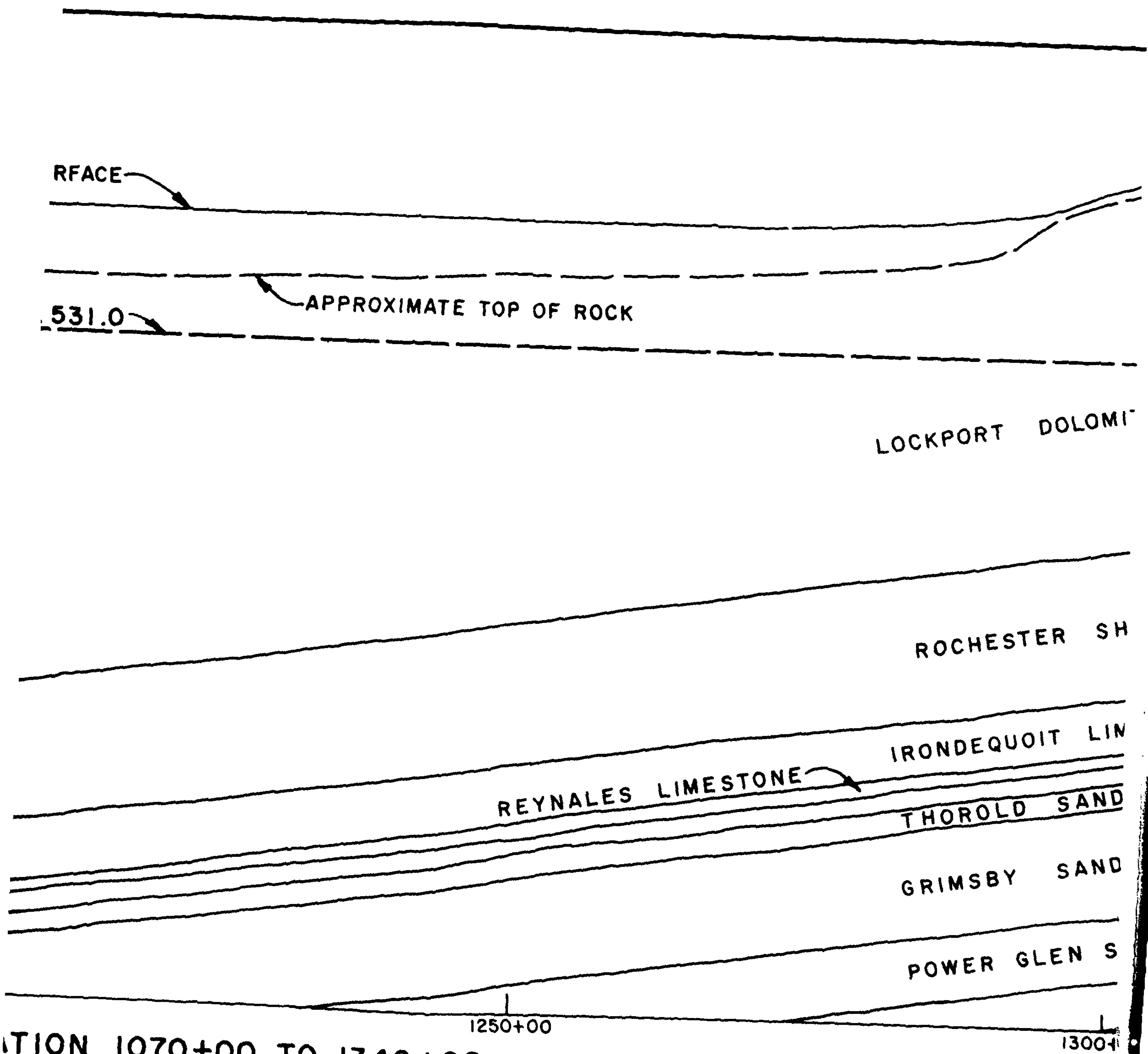
U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973


ELEVATION IN FEET I.G.L.D. (1955)
600
550
500
450
400
350
300
250
CAMILLUS SHALE
1070+00
1100+00



PROFILE ALONG ALIGNMENT A-1 FROM STATION 1070



ATION 1070+00 TO 1340+00

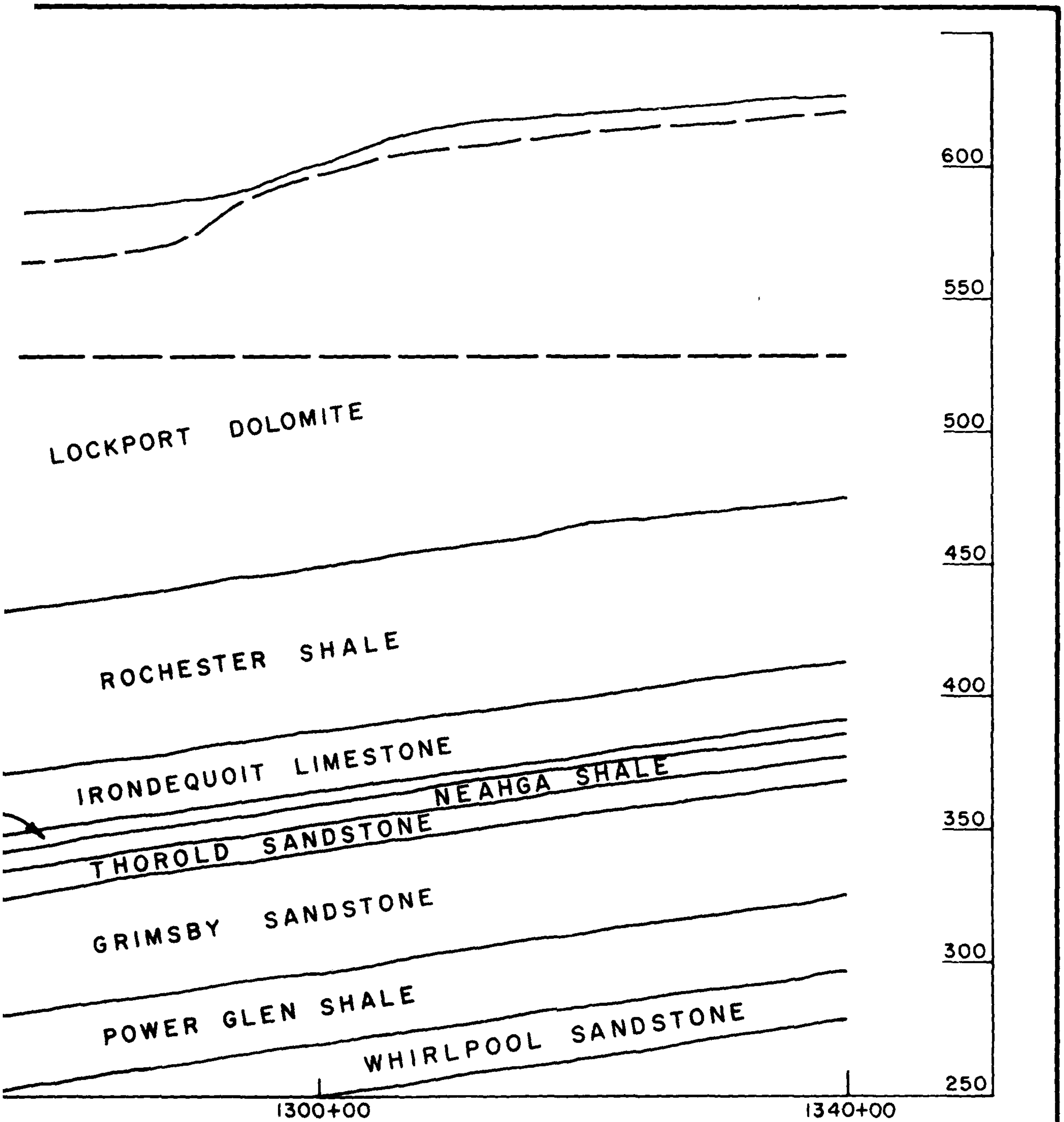
SHEET INDEX

THIS PLATE B8	SEE PLATE B9	SEE PLATE B10

NOTES

TOP OF
FROM I

FOR GE
COLUM



EX

SEE PLATE B10

NOTES:

TOP OF ROCK LINE DERIVED FROM PLATE B7

FOR GENERALIZED GEOLOGIC COLUMN SEE PLATE B1

LAKE ERIE-LAKE ONTARIO WATERWAY

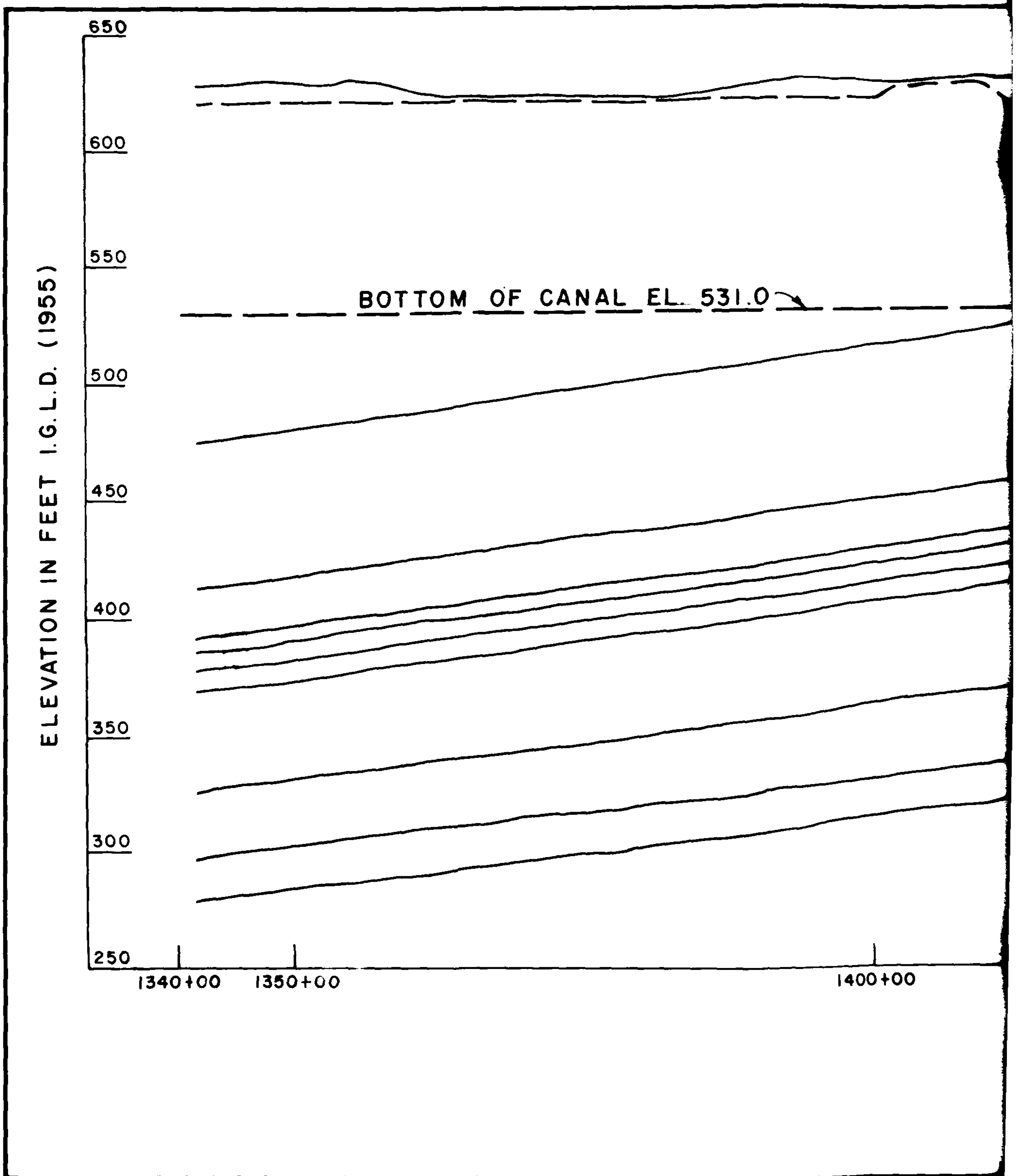
GEOLOGIC PROFILE ALONG OVERLAND SECTION

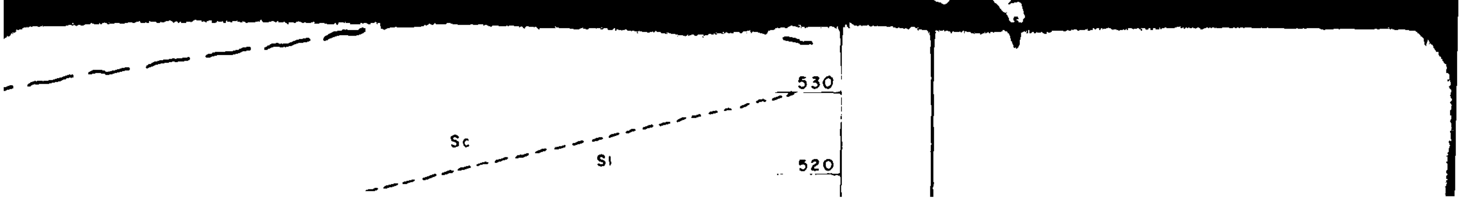
U.S. ARMY ENGINEER DISTRICT, BUFFALO

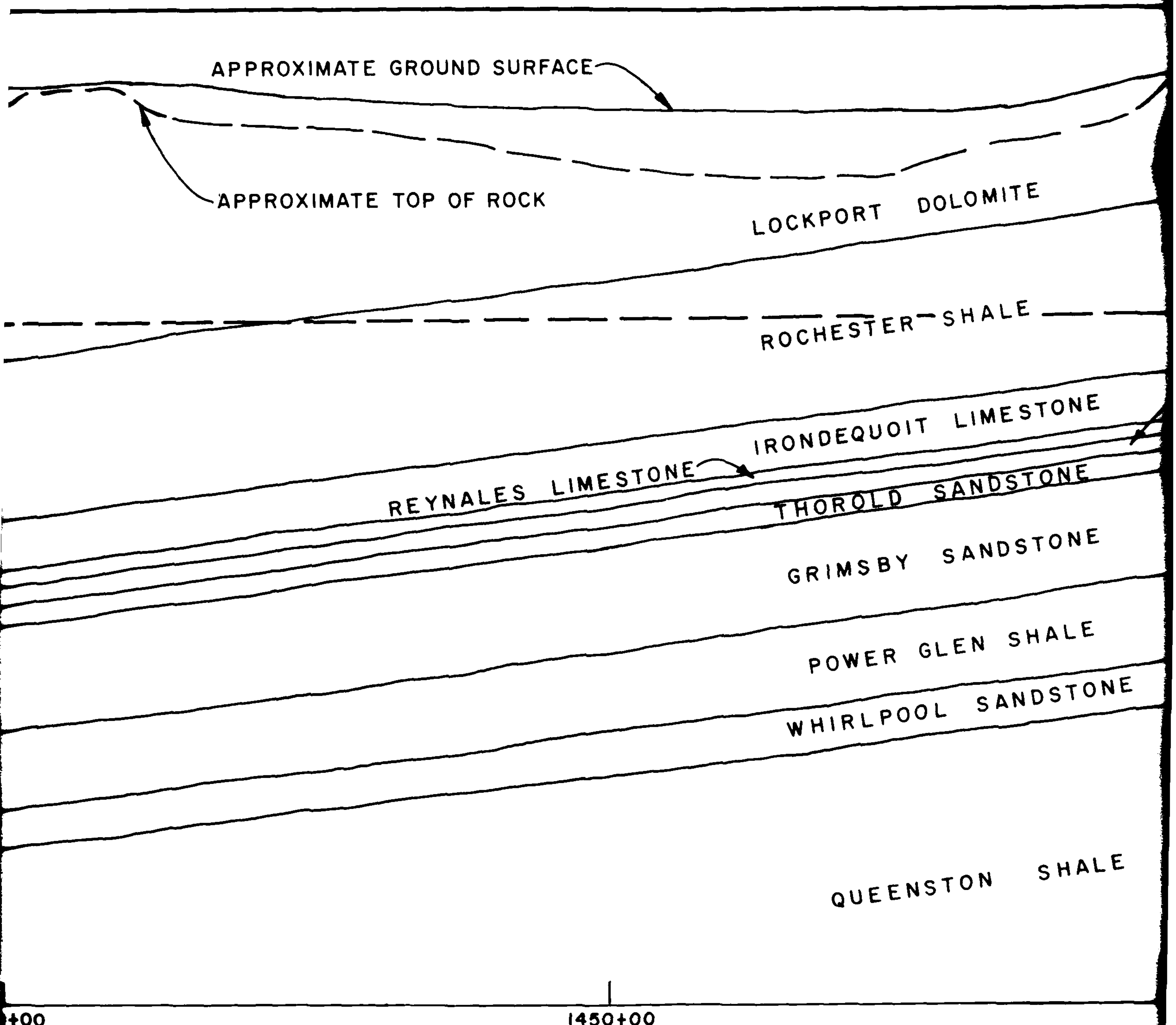
TO ACCOMPANY REVIEW OF REPORTS

OCTOBER 1973

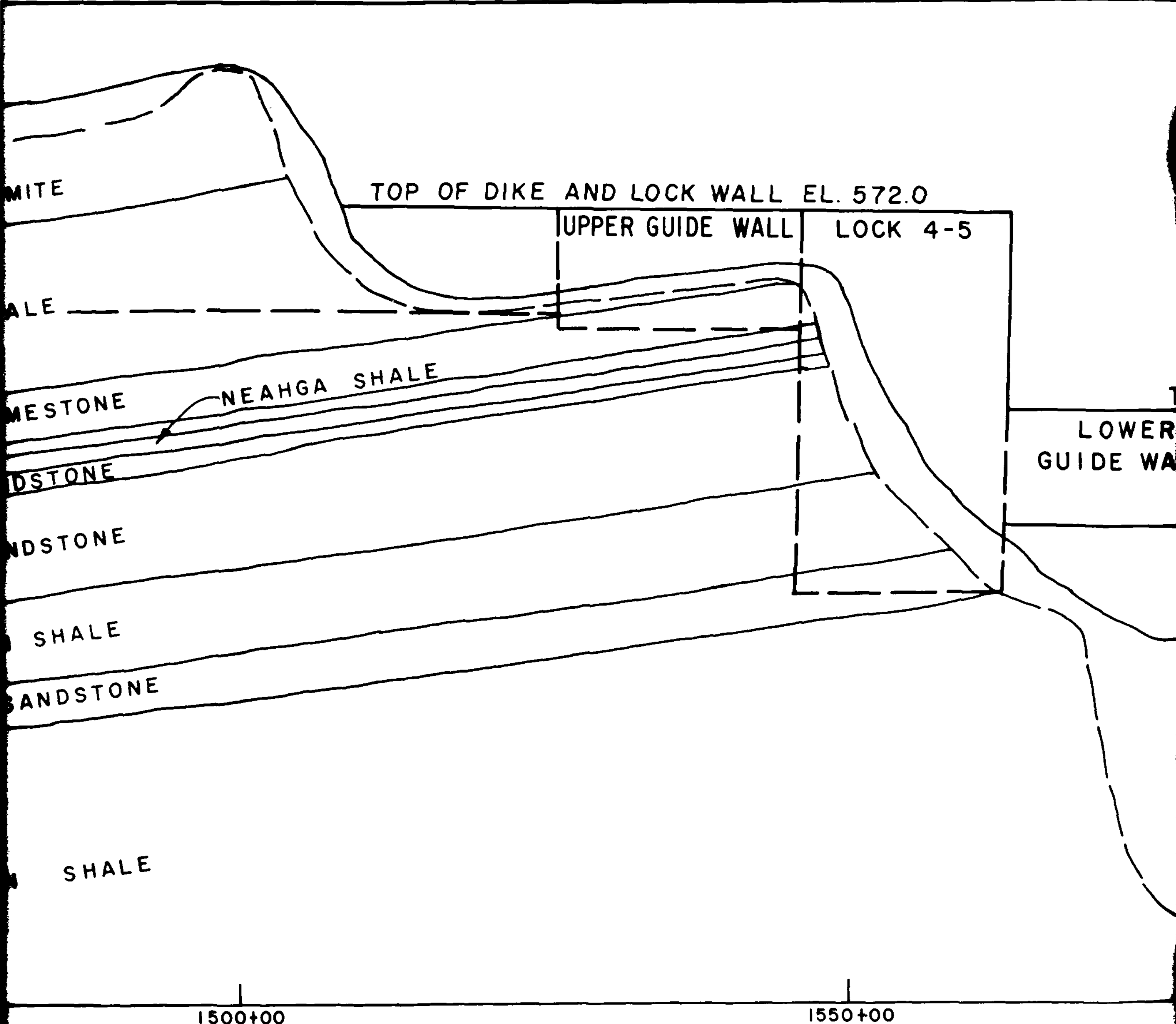
PLATE B8


650
600
550
500
450
400
350
300
250
ELEVATION IN FEET I.G.L.D. (1955)
BOTTOM OF CANAL EL. 531.0
1340+00
1350+00
1400+00


530
520
Sc
Si



PROFILE ALONG ALIGNMENT A-1 FROM STATION



STATION 1340+00 TO 1600+00

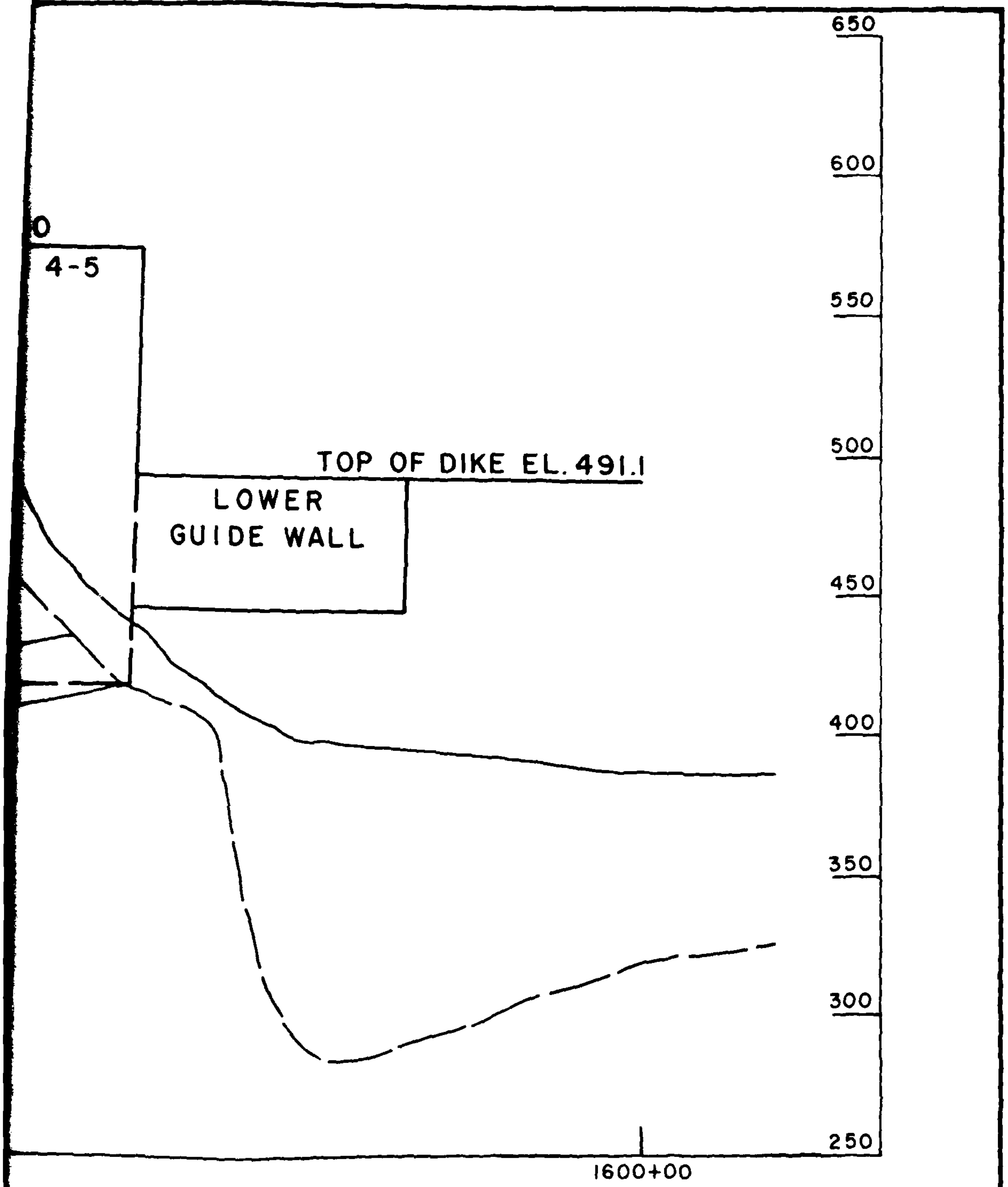
SHEET INDEX

SEE PLATE B8	THIS PLATE B9	SEE PLATE B10

NOTES:

TOP OF ROC
FROM PLATE

FOR GENERA
COLUMN SEE



TE

NOTES:

TOP OF ROCK LINE DERIVED FROM PLATE B7

FOR GENERALIZED GEOLOGIC COLUMN SEE PLATE B1

LAKE ERIE-LAKE ONTARIO WATERWAY

GEOLOGIC PROFILE ALONG OVERLAND SECTION

U.S. ARMY ENGINEER DISTRICT, BUFFALO

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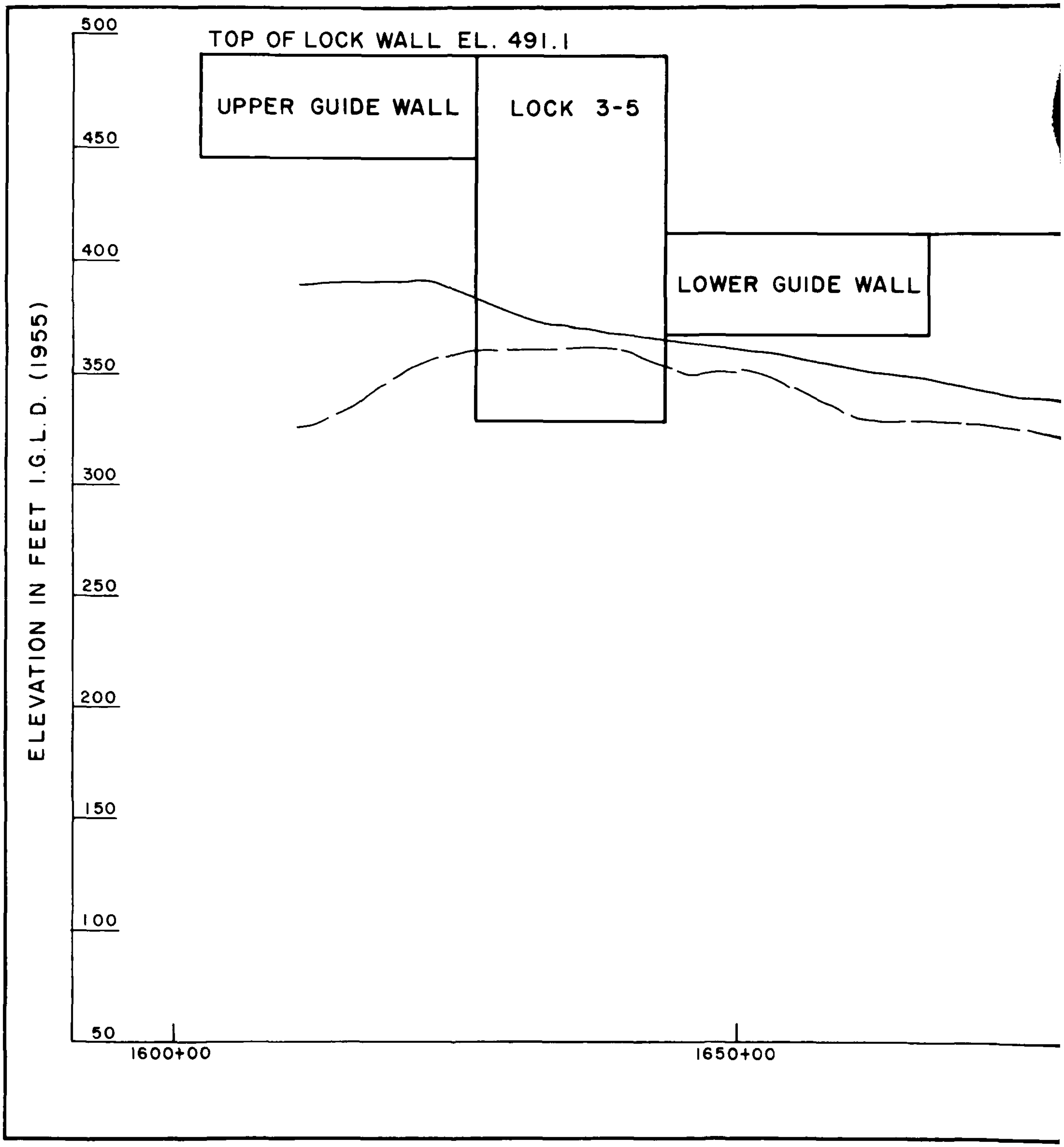
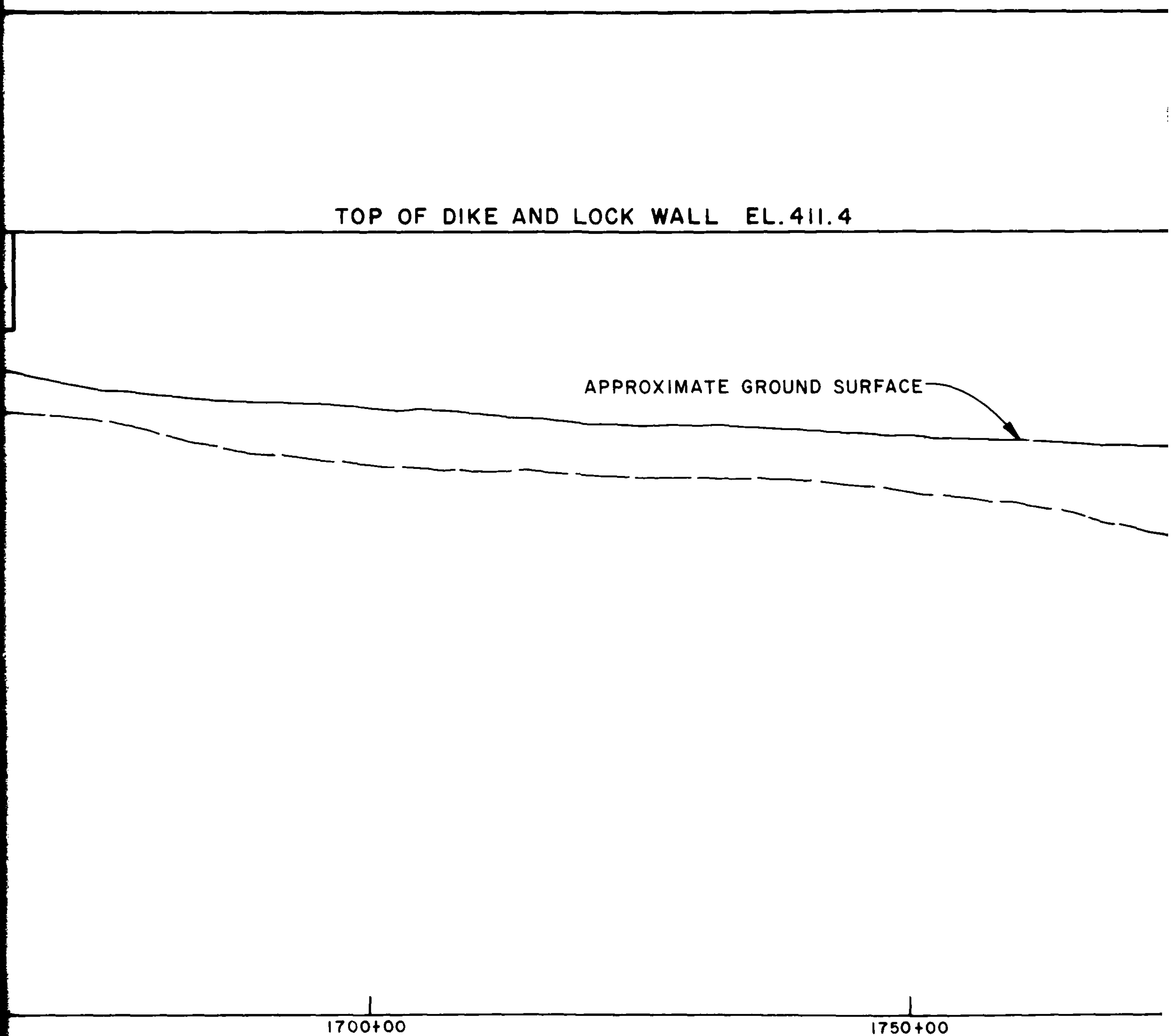
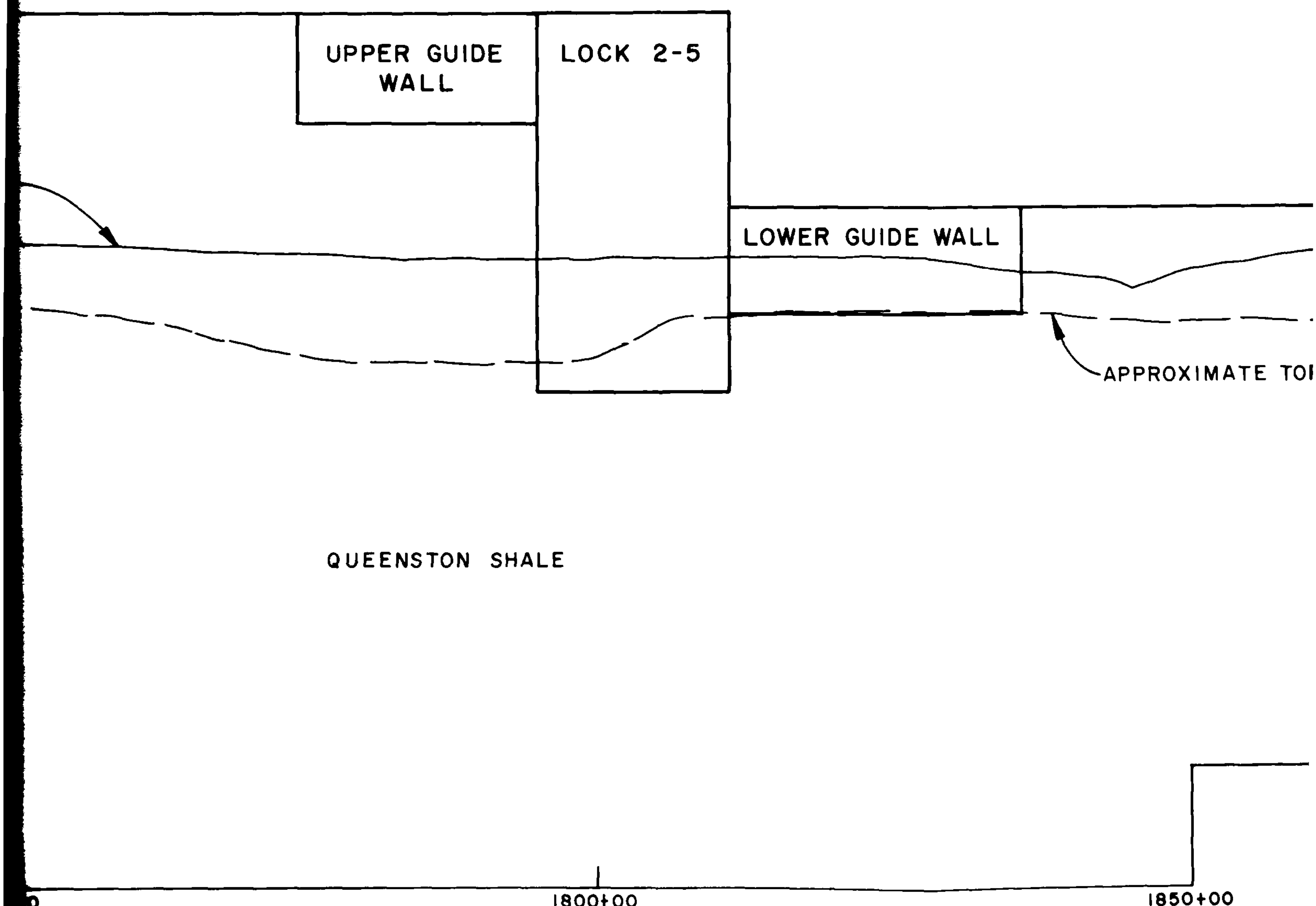
OCTOBER 1973


TOP OF LOCK WALL EL. 491.1
UPPER GUIDE WALL
LOCK 3-5
LOWER GUIDE WALL
ELEVATION IN FEET I.G.L.D. (1955)
500
450
400
350
300
250
200
150
100
50
1600+00
1650+00

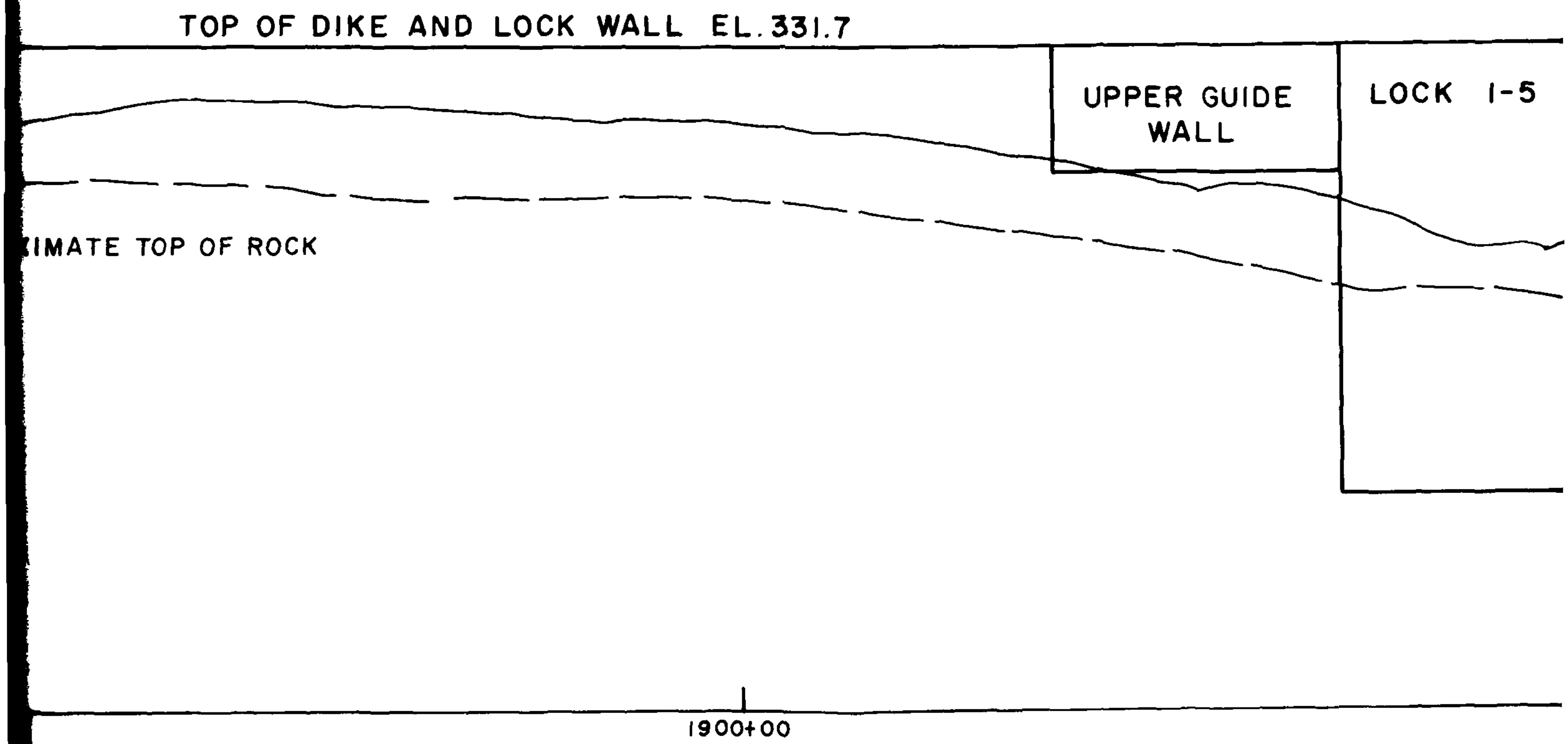


PROFILE ALONG ALIGNM

4



ALONG ALIGNMENT A-1 FROM STATION 1600+00 TO 1977+00



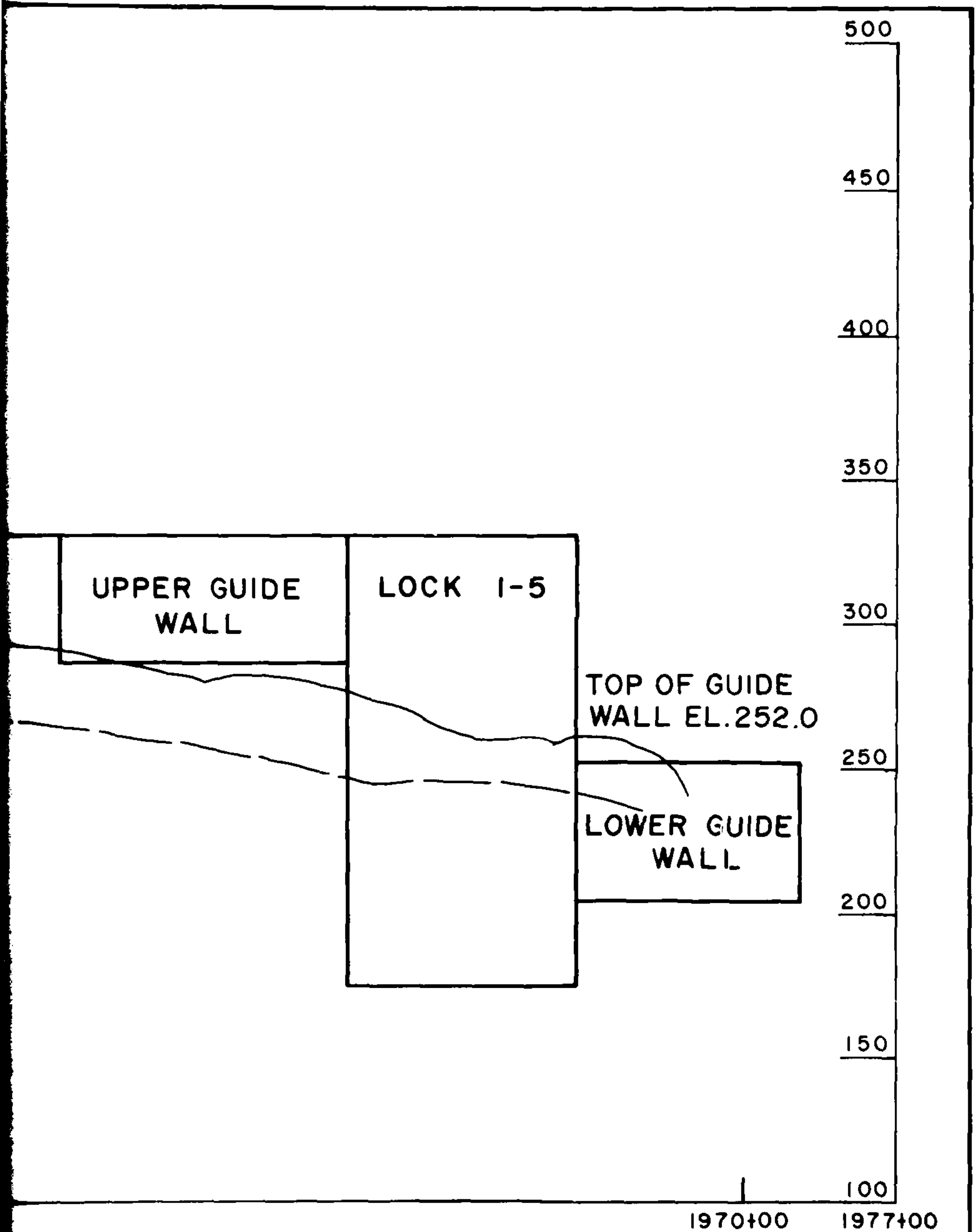
SHEET INDEX

+00	SEE PLATE B8	SEE PLATE B9	THIS PLATE B10

NOTES:

TOP OF ROCK LINE DERIVED FROM PLATE B7

FOR GENERALIZED GEOLOGIC COLUMN SEE PLATE B1



ES:

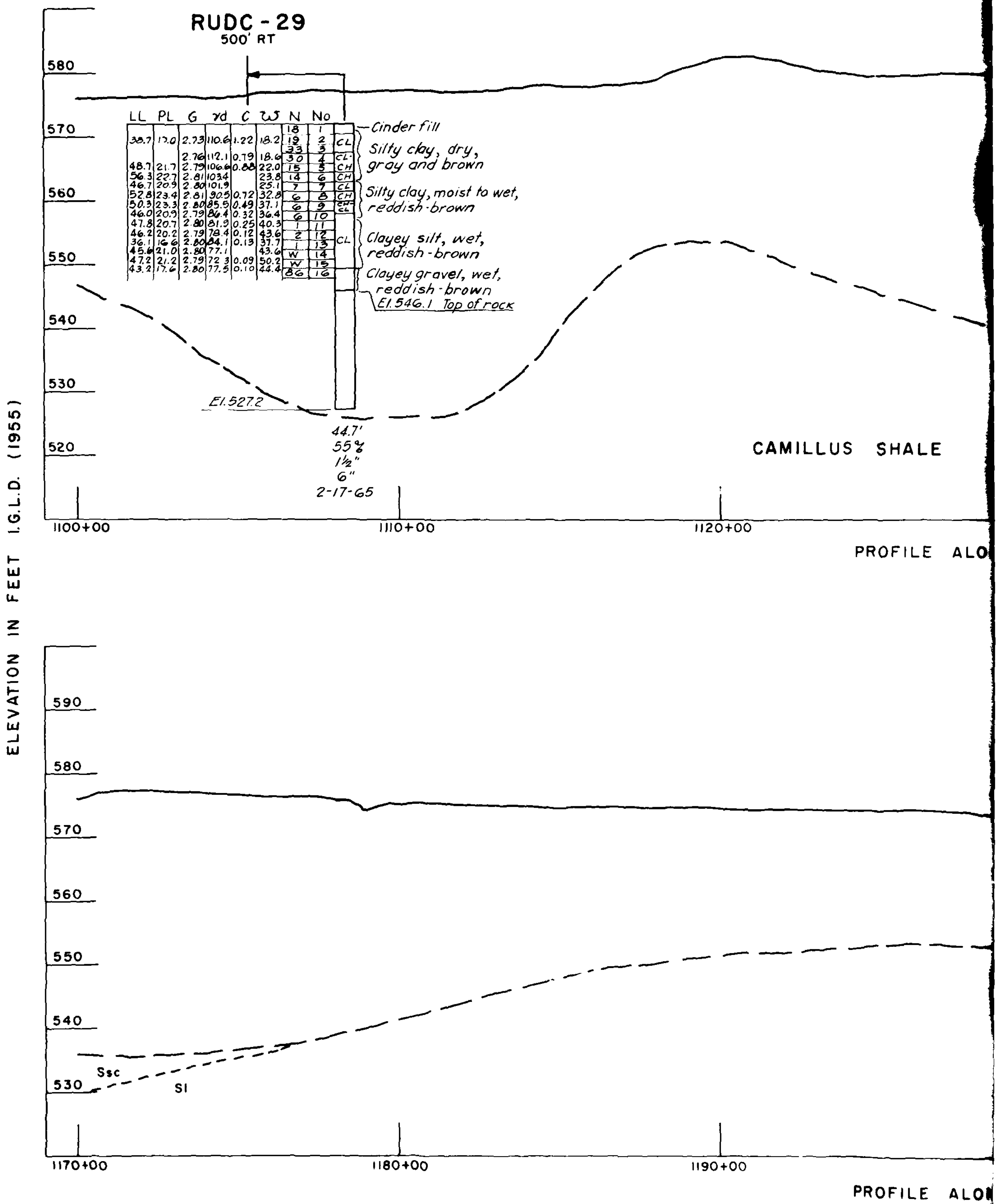
OP OF ROCK LINE DERIVED
M PLATE B7
OR GENERALIZED GEOLOGIC
OMN SEE PLATE B1

LAKE ERIE-LAKE ONTARIO WATERWAY

GEOLOGIC PROFILE
ALONG OVERLAND SECTION

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

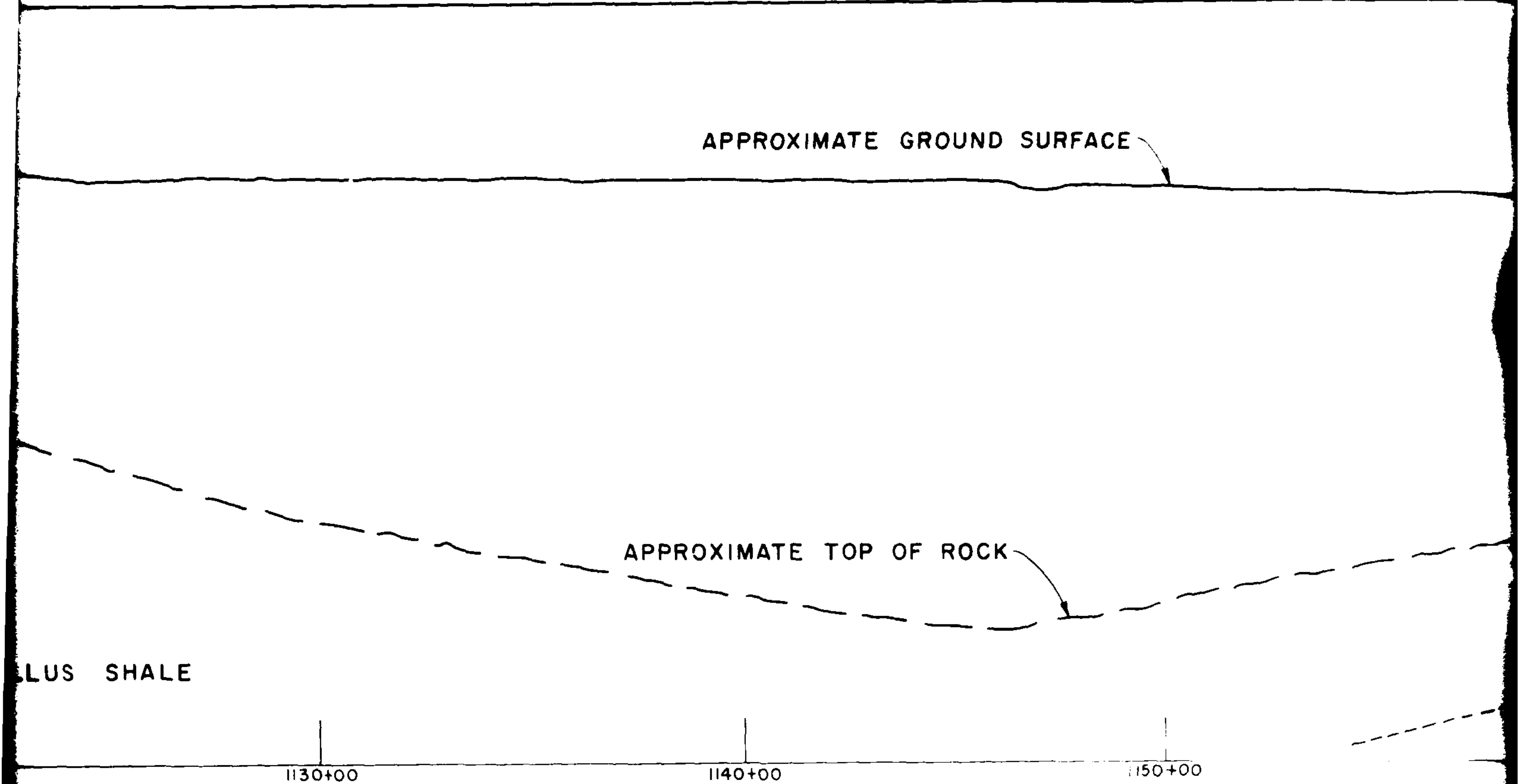
PLATE B10



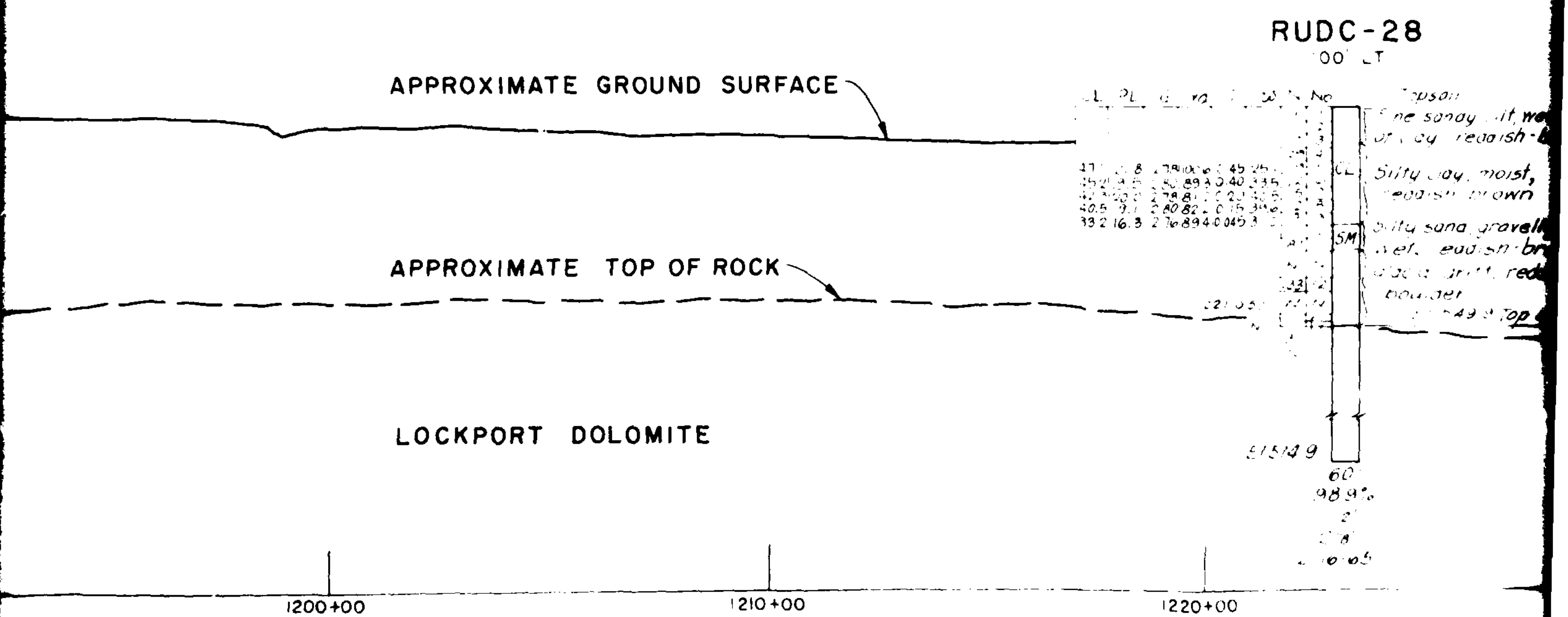
LL	PL	G	γd	C	ω	N	No	
						18	1	
38.7	17.0	2.73	110.6	1.22	18.2	19	2	CL
						33	3	
		2.76	112.1	0.79	18.6	30	4	CL-
48.7	21.7	2.79	106.6	0.88	22.0	15	5	CH
56.3	22.7	2.81	103.4		23.8	14	6	CH
46.7	20.9	2.80	101.9		25.1	7	7	CL
52.8	23.4	2.81	90.5	0.72	32.8	6	8	CH
50.3	23.3	2.80	85.5	0.49	37.1	6	9	CH-CL
46.0	20.9	2.79	86.4	0.32	36.4	6	10	
47.8	20.7	2.80	81.9	0.25	40.3	1	11	
46.2	20.2	2.79	78.4	0.12	43.6	2	12	CL
36.1	16.6	2.80	84.1	0.13	37.7	1	13	
45.6	21.0	2.80	77.1		43.6	W	14	
47.2	21.2	2.79	72.3	0.09	50.2	W	15	
43.2	17.6	2.80	77.5	0.10	44.4	86	16	

LEGEND FOR LOGS OF BORINGS FOR SOIL PROFILES

BORING NUMBER AND DESIGNATION —— RUDC - 28
OFFSET FROM CENTERLINE CANAL —— 100' RT



PROFILE ALONG ALIGNMENT A-I FROM STATION 1100+00 TO 1170+00

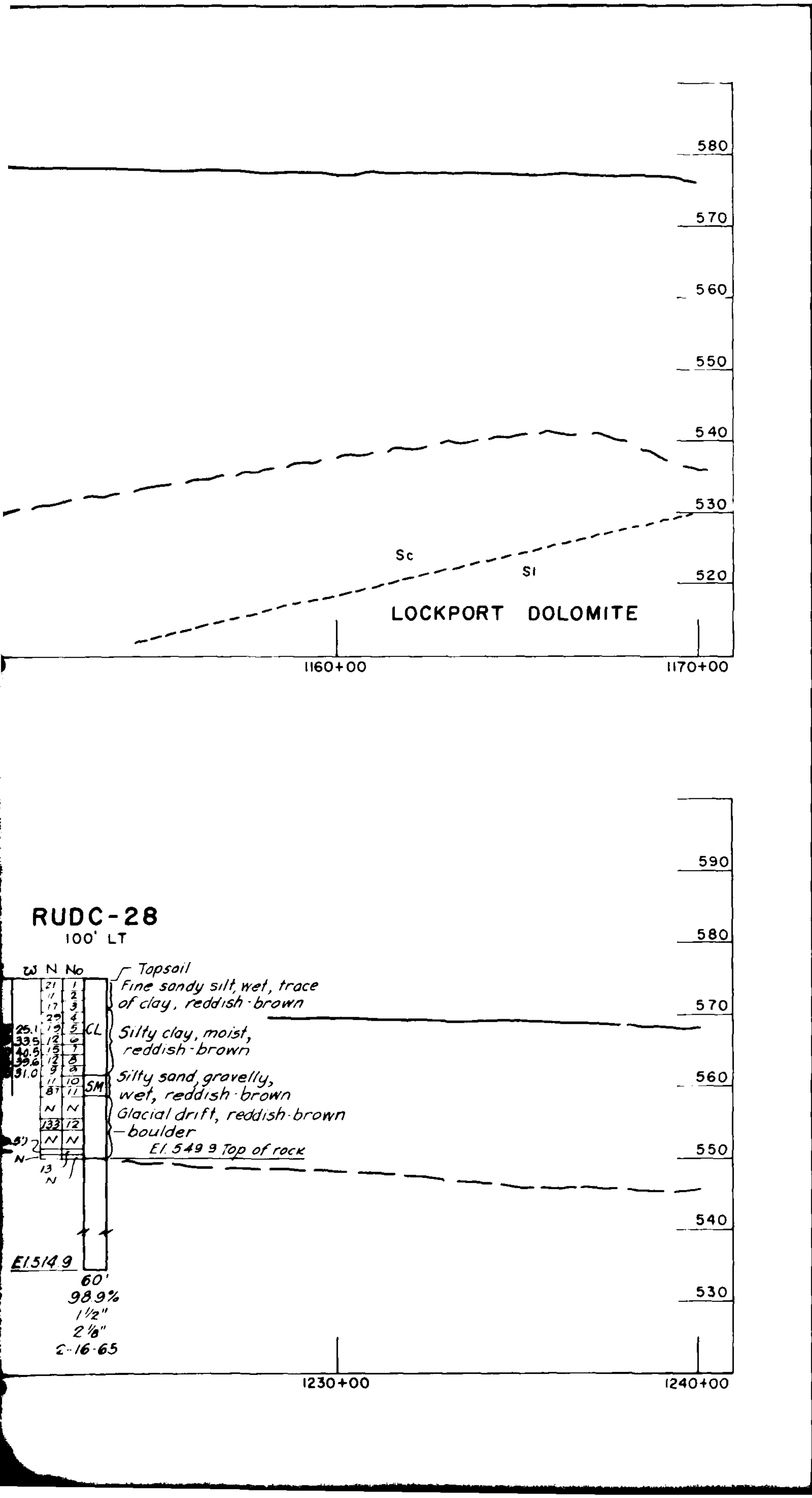


PROFILE ALONG ALIGNMENT A-I FROM STATION 1170+00 TO 1240+00

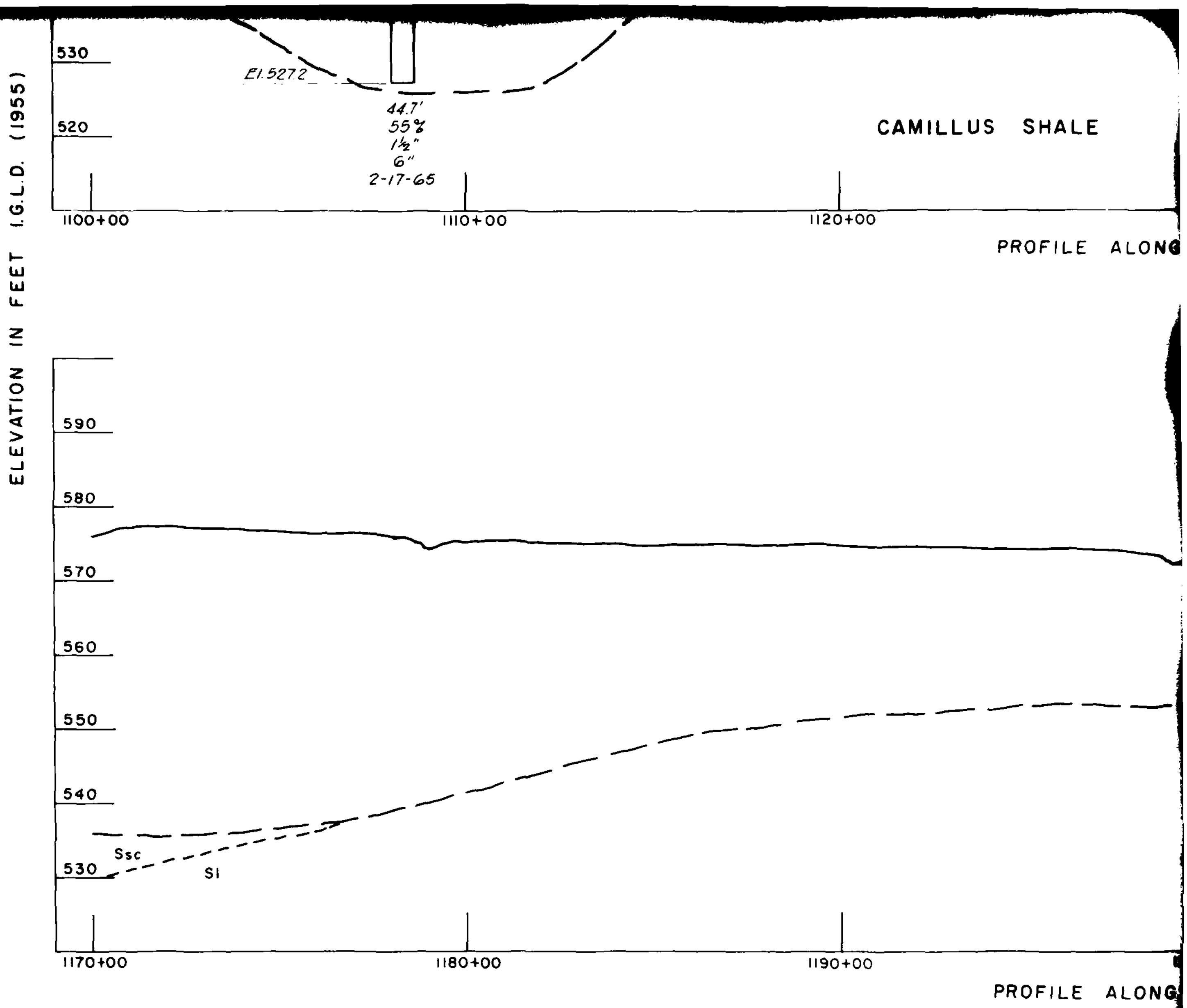
NOTES:

FOR LOCATION OF BORINGS SEE PLATE 85.

FOR UNIFIED SOIL CLASSIFICATION SYSTEM AND



580
570
560
550
540
530
520
Sc
Sl
LOCKPORT DOLOMITE
1160+00
1170+00
590
RUDC-28
100' LT
W N No
CL
SM
Topsoil
Fine sandy silt, wet, trace of clay, reddish-brown
Silty clay, moist, reddish-brown
Silty sand, gravelly, wet, reddish-brown
Glacial drift, reddish-brown
-boulder
El. 549.9 Top of rock
El. 514.9
60'
98.9%
1½"
2⅛"
2-16-65
1230+00
1240+00

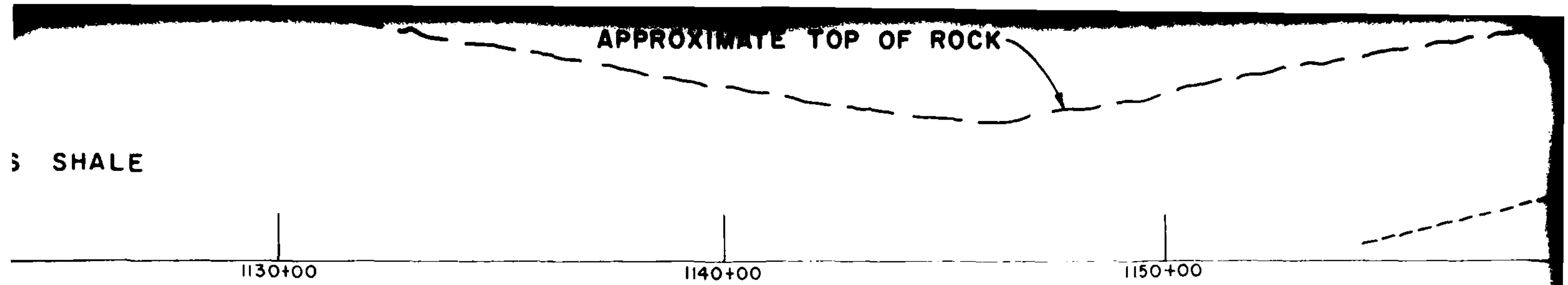


LEGEND FOR LOGS OF BORINGS FOR SOIL PROFILES

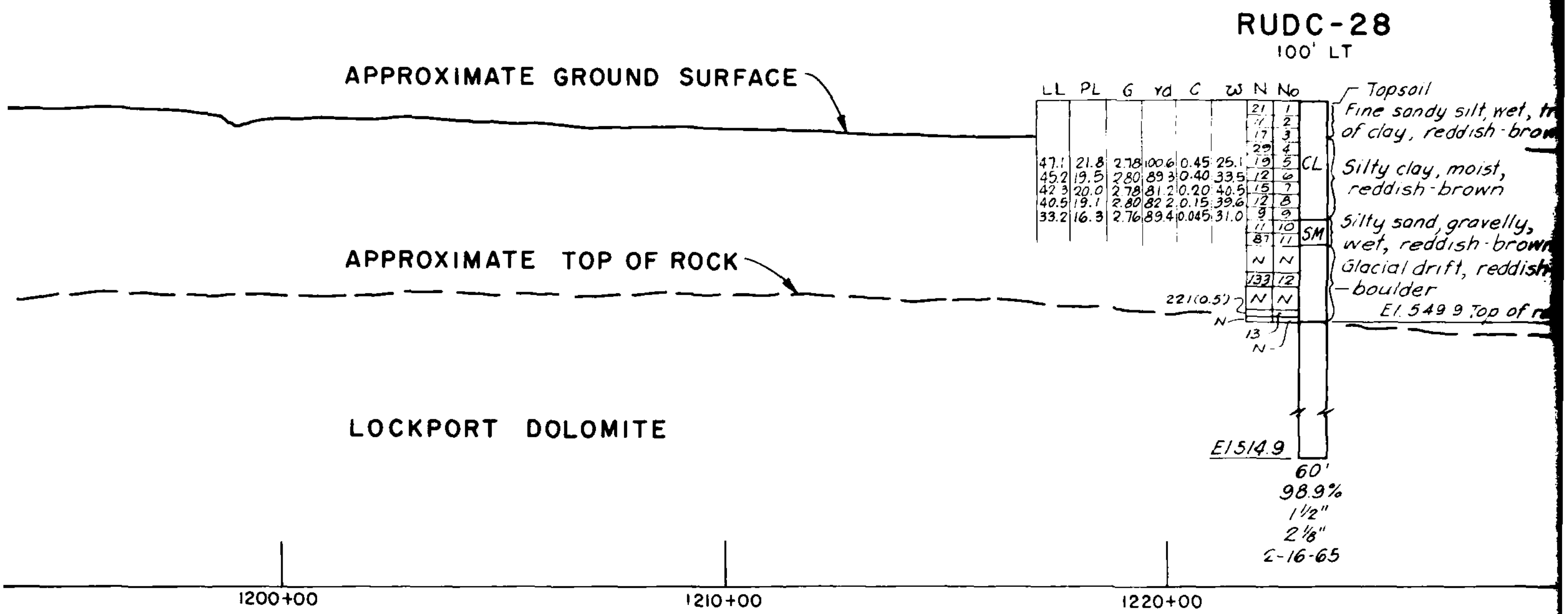
BORING NUMBER AND DESIGNATION — RUDC - 28
OFFSET FROM CENTERLINE CANAL — 100' RT

LL PL G Yd C ω N No

SAMPLE NUMBER — 1
BLOWS PER FOOT ON SPLIT SPOON SAMPLER — 62
MOISTURE CONTENT, PERCENT DRY WEIGHT — 20.7
COHESION, TONS PER SQUARE FOOT — 1.20
UNIT DRY WEIGHT, POUNDS PER CUBIC FOOT — 73.2
SPECIFIC GRAVITY — 2.80
PLASTIC LIMIT — 29
LIQUID LIMIT — 43
UNIFIED SOIL CLASSIFICATION SYMBOL — CL
BOTTOM OF HOLE ELEVATION — EL. 514.9
DEPTH OF HOLE — 60'
PERCENT RECOVERY IN BEDROCK — 98.9%
DIAMETER OF SOIL SAMPLES — 1½"
DIAMETER OF BEDROCK CORE — 2⅛"
DATE BORING COMPLETED — 2-16-65



PROFILE ALONG ALIGNMENT A-1 FROM STATION 1100+00 TO 1170+00



PROFILE ALONG ALIGNMENT A-1 FROM STATION 1170+00 TO 1240+00

NOTES:

FOR LOCATION OF BORINGS SEE PLATE B5.

FOR UNIFIED SOIL CLASSIFICATION SYSTEM AND BORING DESIGNATIONS SEE PLATE B1.

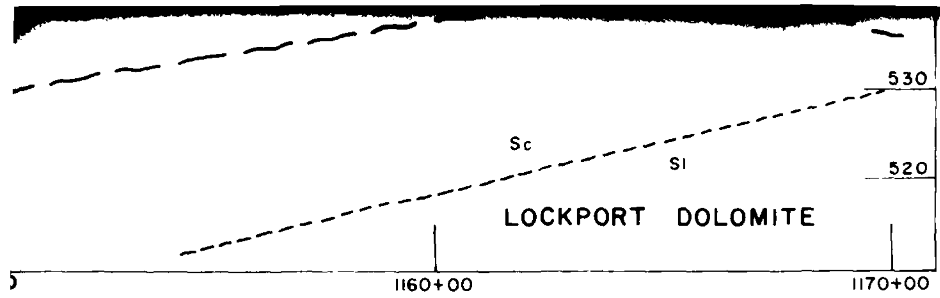
ALL DRIVE SAMPLES WERE OBTAINED WITH A 1½" I.D. STANDARD SPLIT SPOON SAMPLER ADVANCED BY A 140 LB. HAMMER FALLING 30".

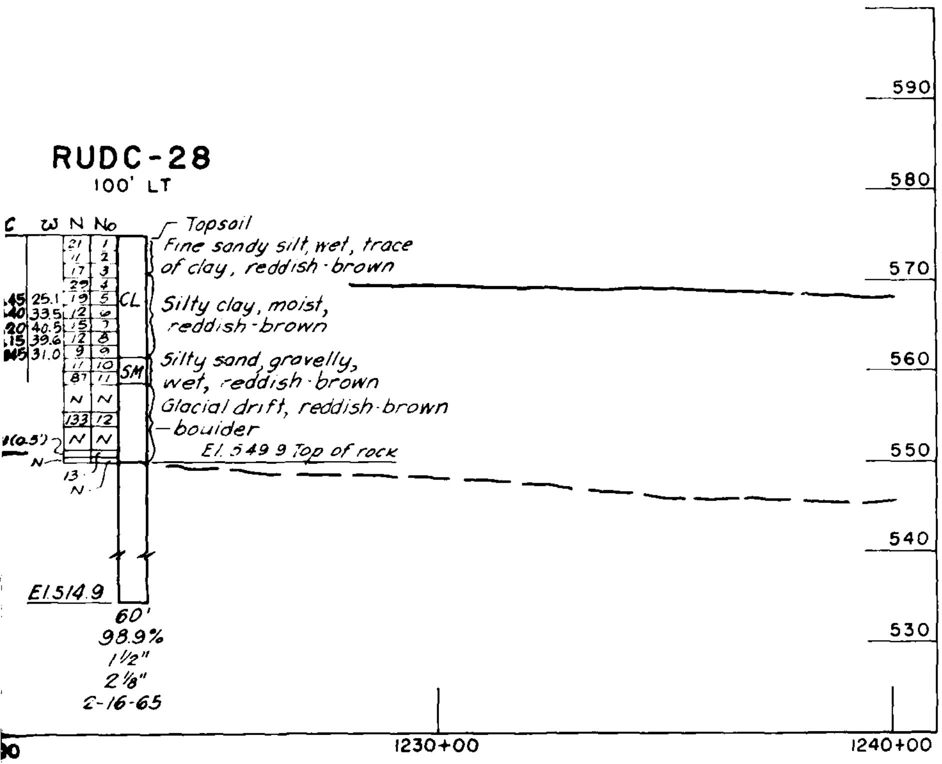
BLOW COUNTS INDICATE THE RELATIVE RESISTANCE OF THE SOIL TO PENETRATION BY THE SAMPLER.

TOP OF ROCK LINE DERIVED FROM PLATE B7.

ROCK CORE INFORMATION FROM BOREHOLES WITHIN STATIONING OF LOCKS AND THEIR GUIDE WALLS ARE GIVEN ON PLATES B20, B21, B22, B23 AND B24.

COMPLETE TEST DATA SUMMARY FOR UNDISTURBED SAMPLES ARE GIVEN ON TABLE B3.





LAKE ERIE–LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1100+00 TO 1240+00 ℄ CANAL

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
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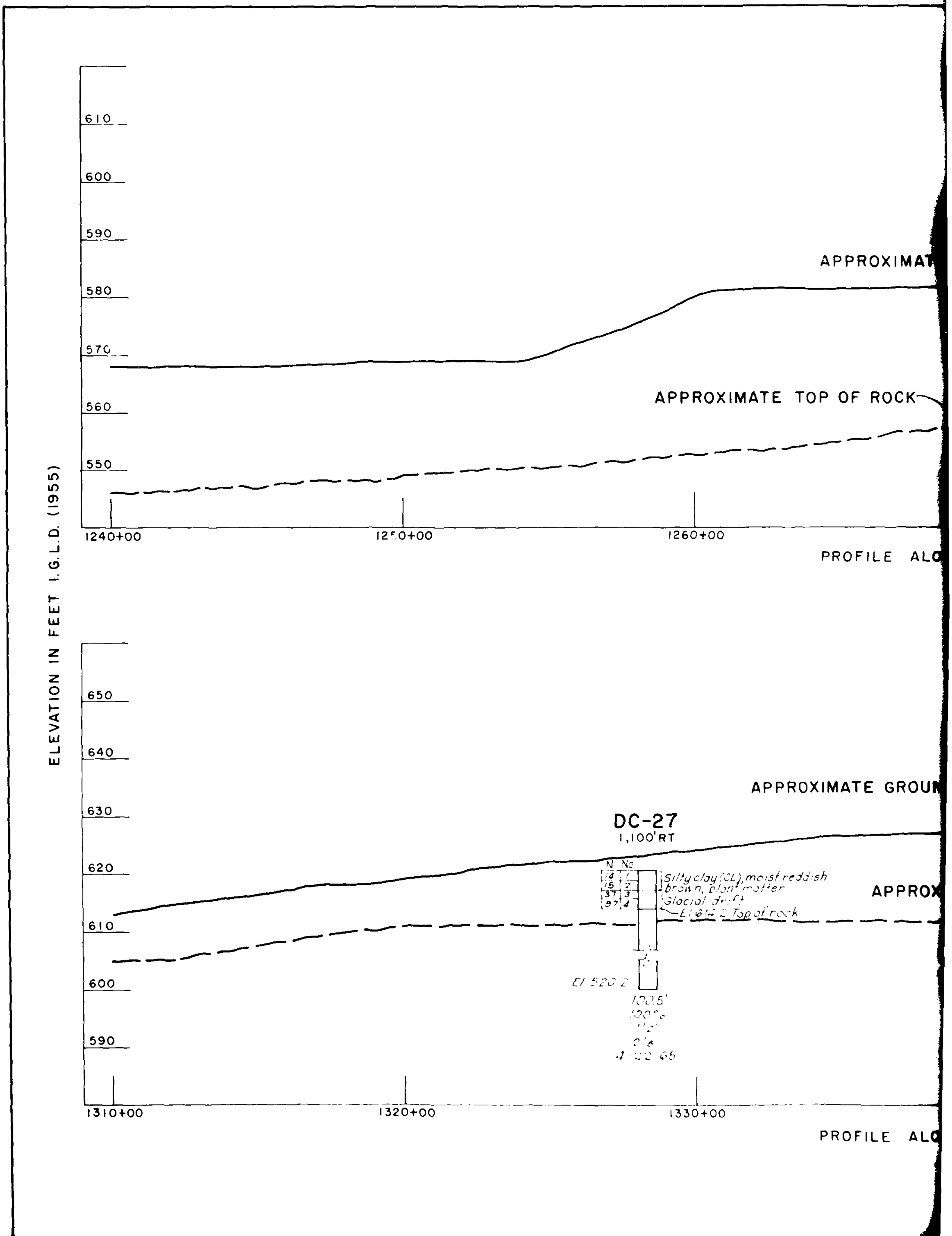
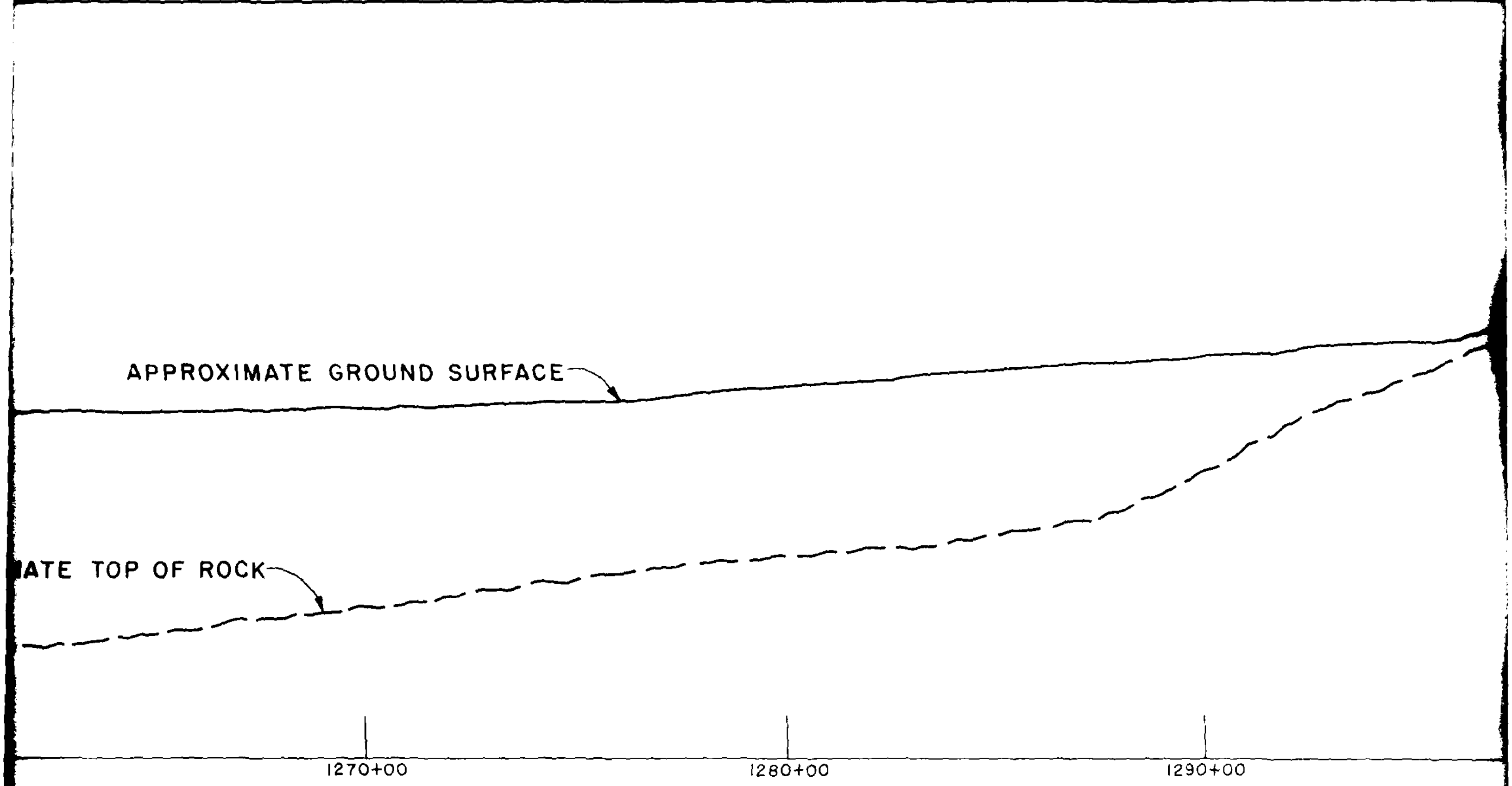
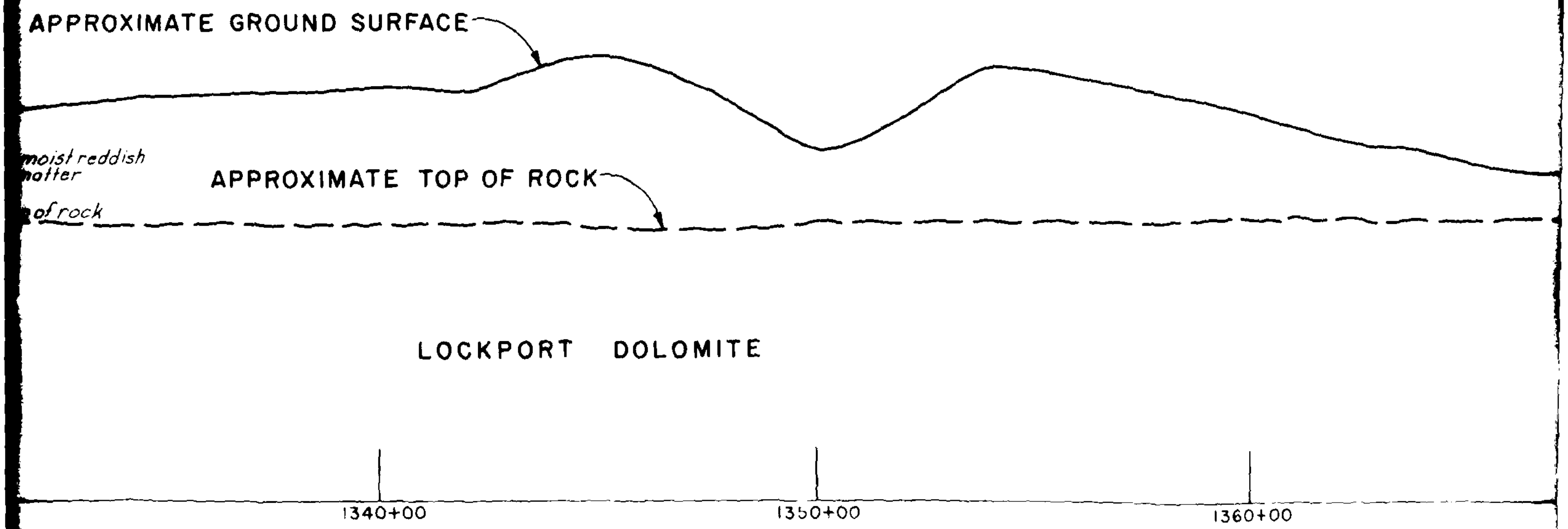
PLATE B11



ELEVATION IN FEET I.G.L.D. (1955)
610
600
590
580
570
560
550
APPROXIMAT
APPROXIMATE TOP OF ROCK
1240+00
1250+00
1260+00
PROFILE ALO
650
640
630
620
610
600
590
APPROXIMATE GROUN
DC-27
1,100'RT
N No
14 1
15 2
37 3
97 4
Silty clay (CL), moist reddish brown, plant matter
Glacial drift
El 614.2 Top of rock
El 520.2
100.5'
APPROX
1310+00
1320+00
1330+00
PROFILE ALO

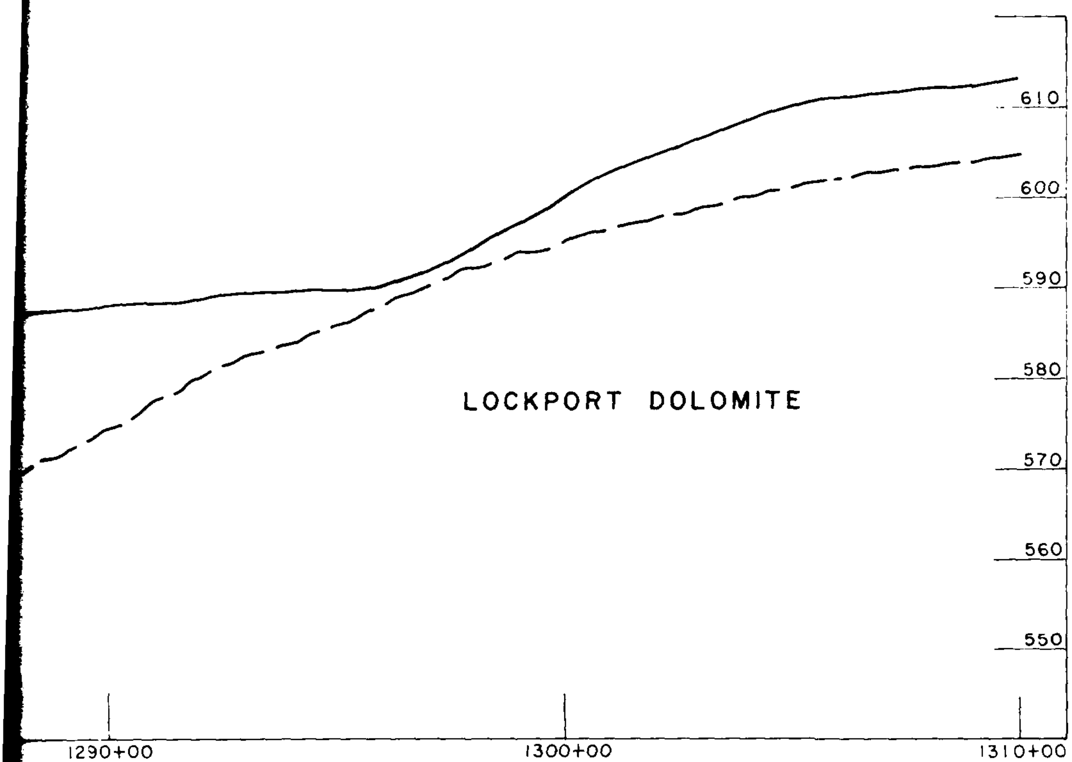


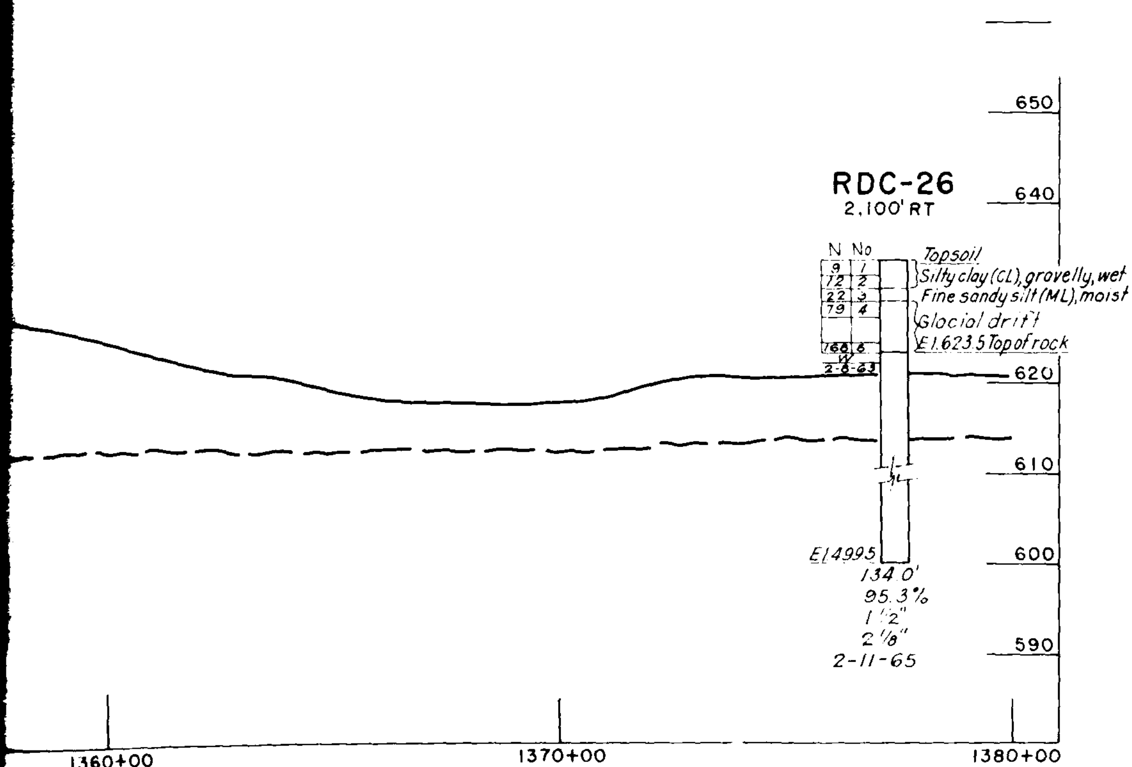
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1240+00 TO 1310+00

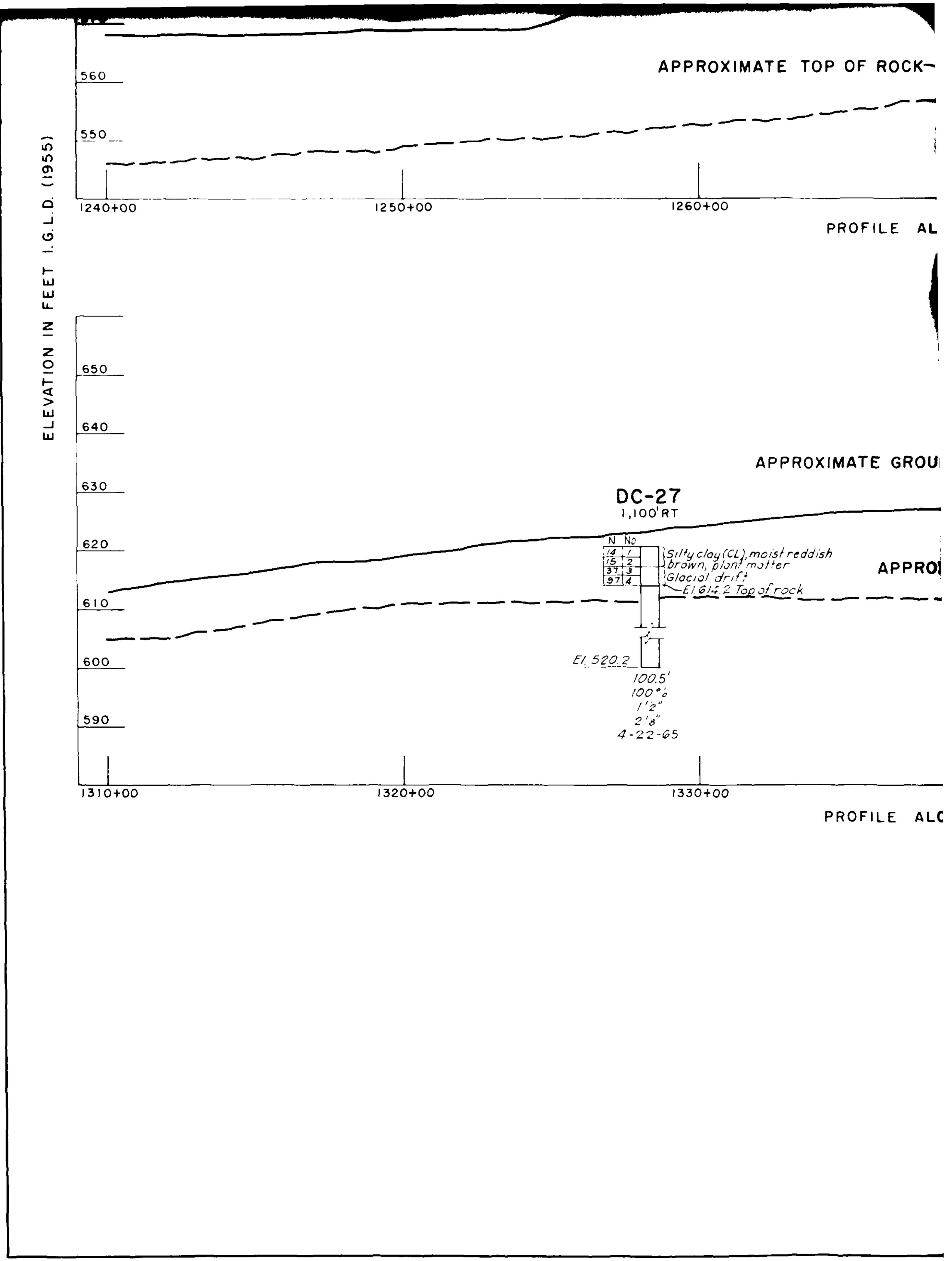


PROFILE ALONG ALIGNMENT A-1 FROM STATION 1310+00 TO 1380+00

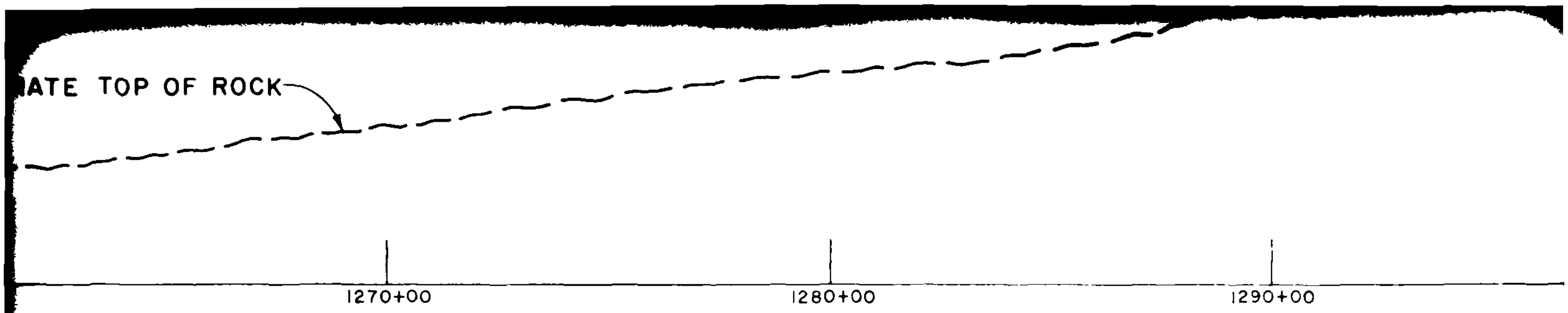
NOTES:


610
600
590
580
LOCKPORT DOLOMITE
570
560
550
1290+00
1300+00
1310+00

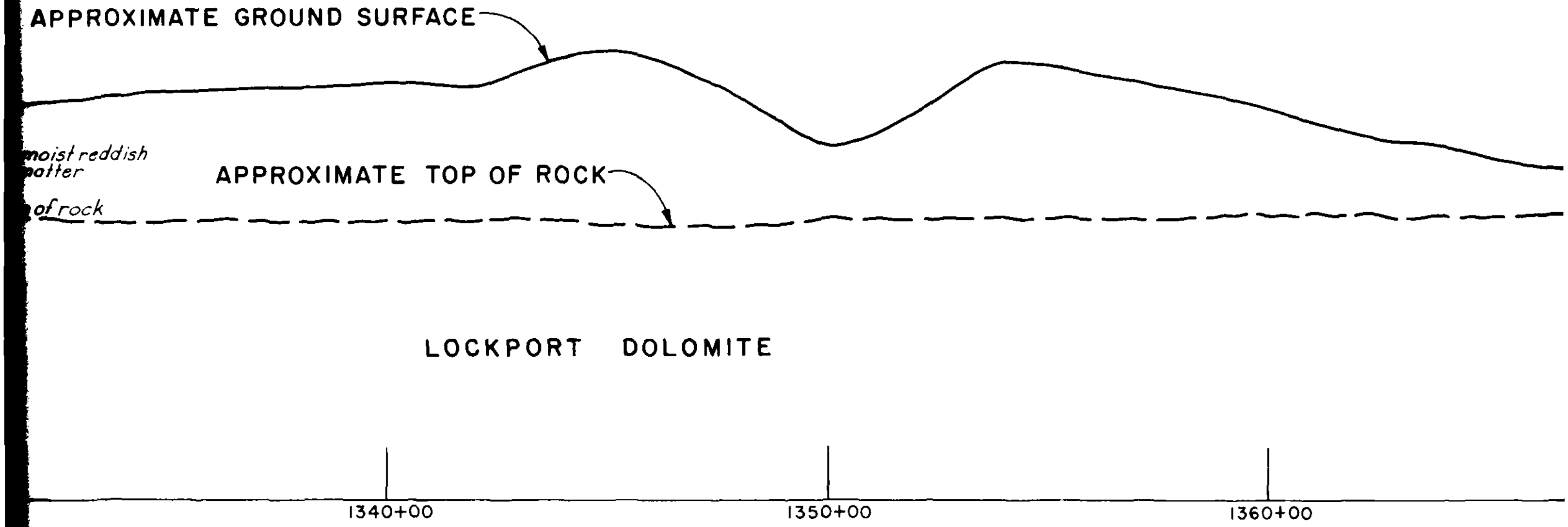

650
640
RDC-26
2,100' RT
N No
9 1
12 2
22 3
79 4
168 6
W
2-8-63
Topsoil
Silty clay (CL), gravelly, wet
Fine sandy silt (ML), moist
Glacial drift
El. 623.5 Top of rock
620
610
El. 499.5
134.0'
95.3%
1 1/2"
2 1/8"
2-11-65
600
590
1360+00
1370+00
1380+00



ELEVATION IN FEET I.G.L.D. (1955)
APPROXIMATE TOP OF ROCK
560
550
1240+00
1250+00
1260+00
PROFILE AL
650
640
630
620
610
600
590
APPROXIMATE GROU
DC-27
1,100'RT
N No
14 1
15 2
37 3
97 4
Silty clay (CL), moist reddish brown, plant matter
Glacial drift
El 614.2 Top of rock
APPRO
El. 520.2
100.5'
100%
1'2"
2'8"
4-22-65
1310+00
1320+00
1330+00
PROFILE ALO



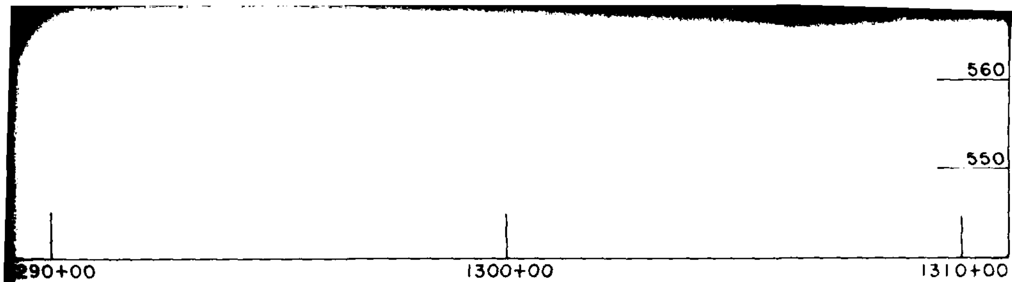
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1240+00 TO 1310+00

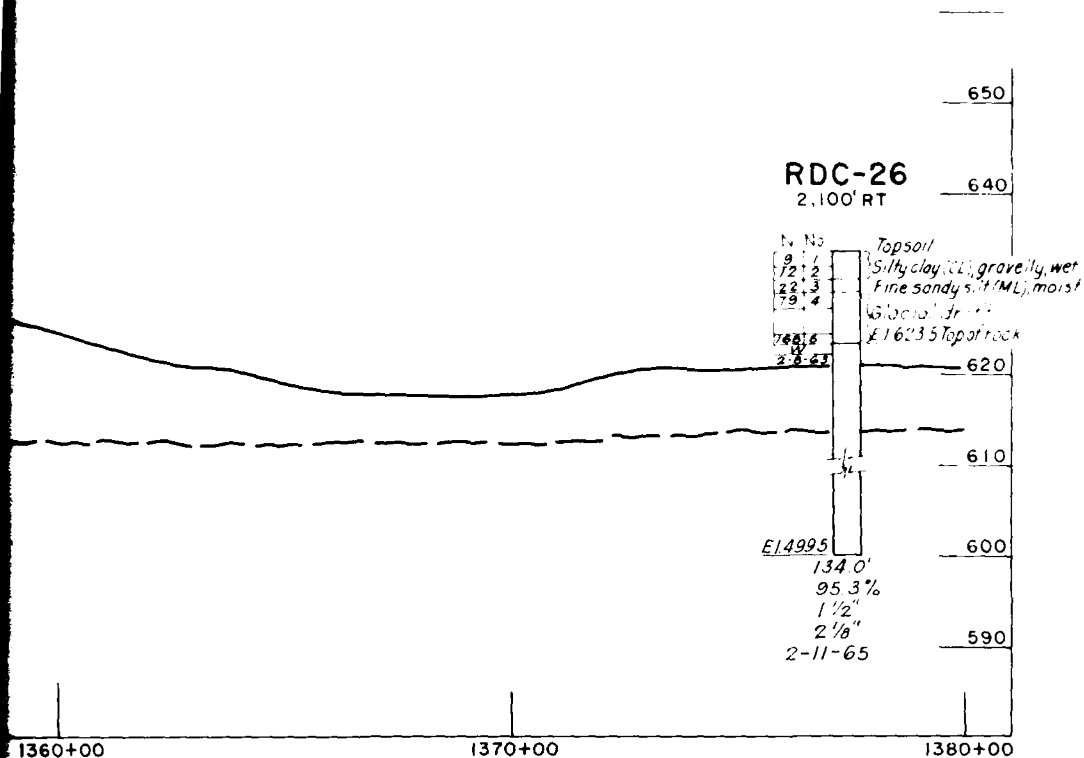


PROFILE ALONG ALIGNMENT A-1 FROM STATION 1310+00 TO 1380+00

NOTES:

FOR LOCATION OF BORINGS SEE PLATE B3.
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS SEE PLATE B11





LAKE ERIE-LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1875+00 TO 1980+00 ℄ CANAL

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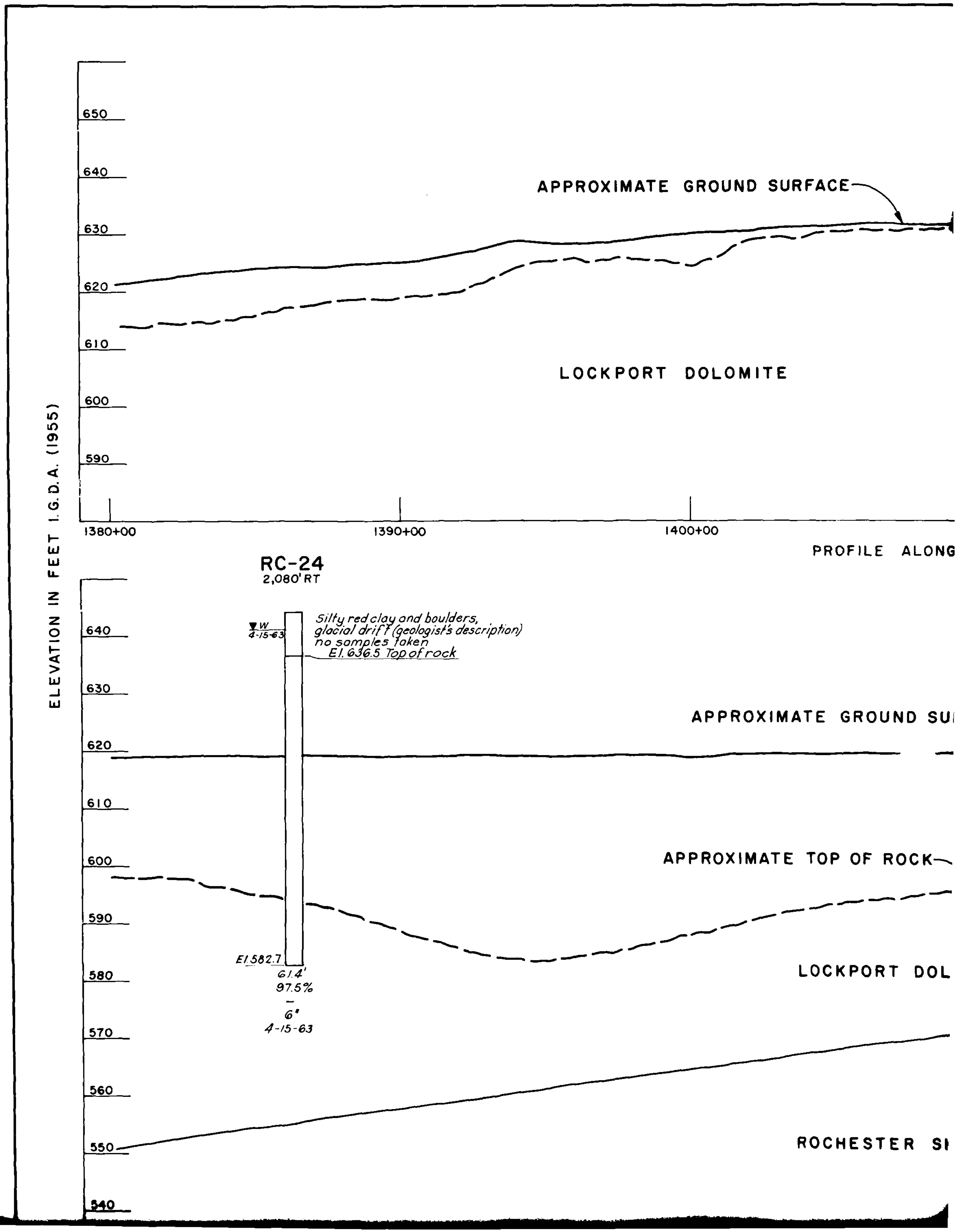
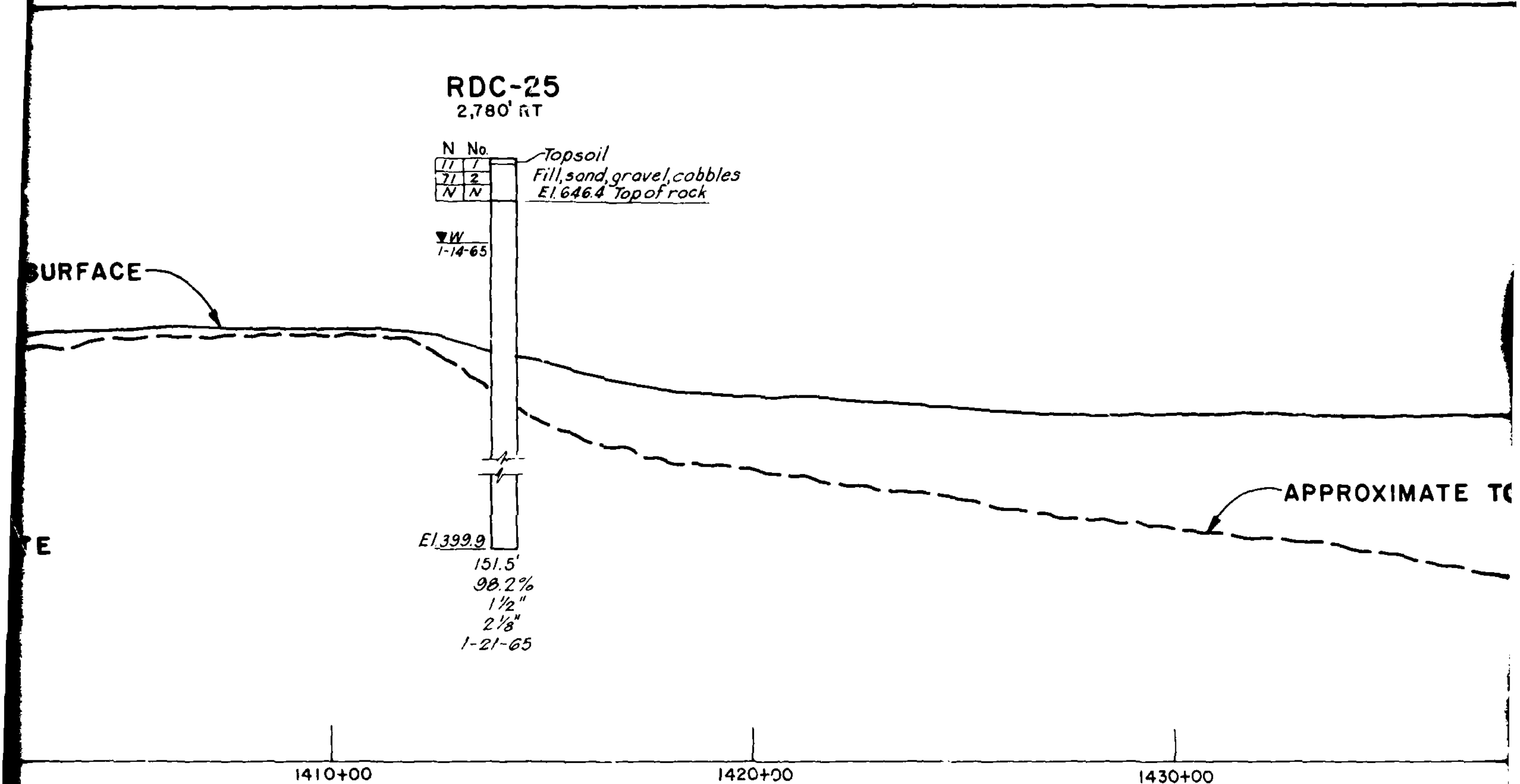
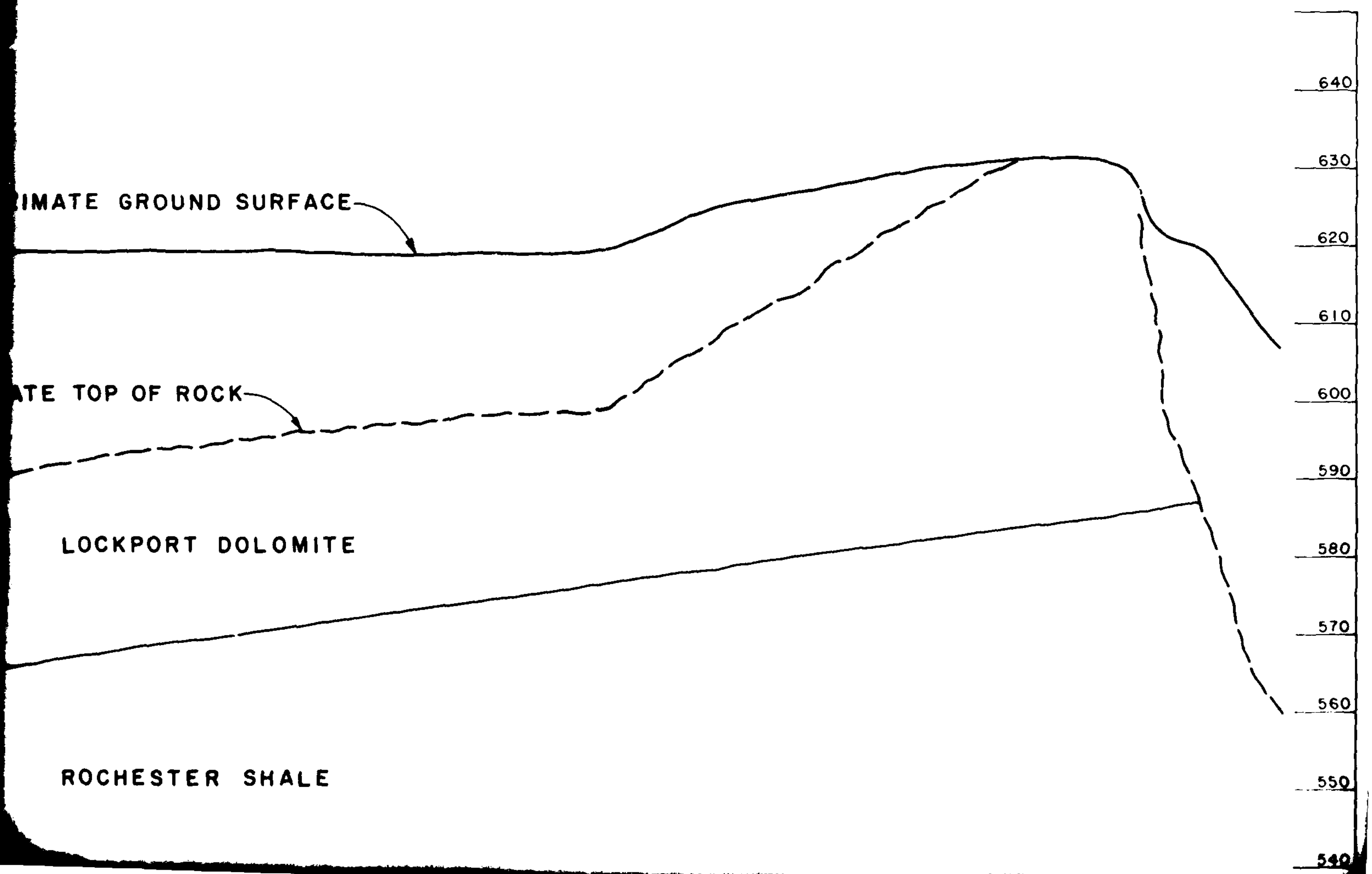
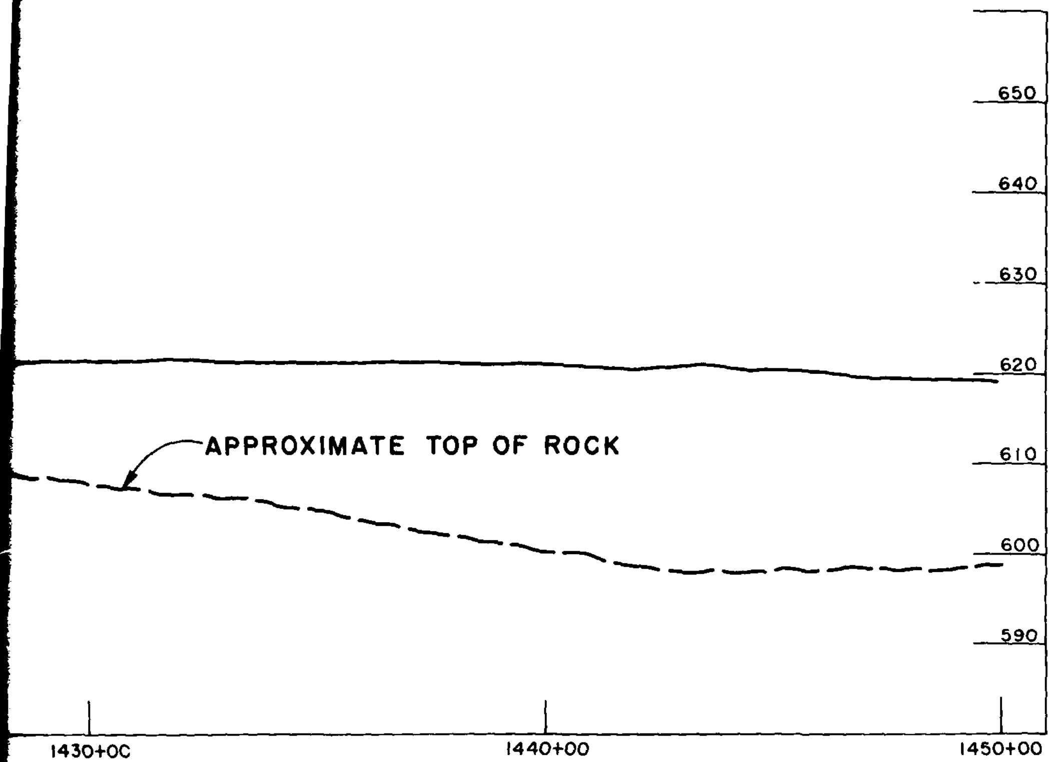


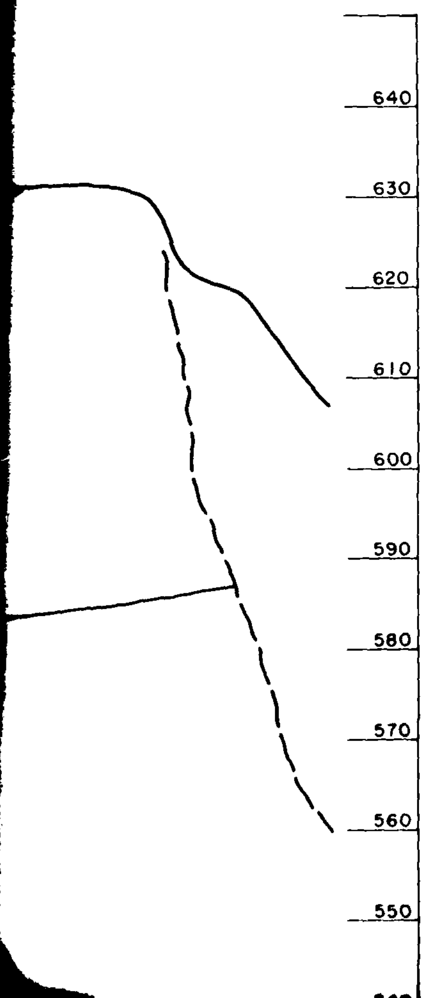
ELEVATION IN FEET I.G.D.A. (1955)
650
640
630
620
610
600
590
APPROXIMATE GROUND SURFACE
LOCKPORT DOLOMITE
1380+00
1390+00
1400+00
PROFILE ALONG
RC-24
2,080' RT
W
4-15-63
Silty red clay and boulders, glacial drift (geologist's description) no samples taken
El. 636.5 Top of rock
640
630
620
610
600
590
580
570
560
550
540
APPROXIMATE GROUND SU
APPROXIMATE TOP OF ROCK
El. 582.7
61.4'
97.5%
6"
4-15-63
LOCKPORT DOL
ROCHESTER SI

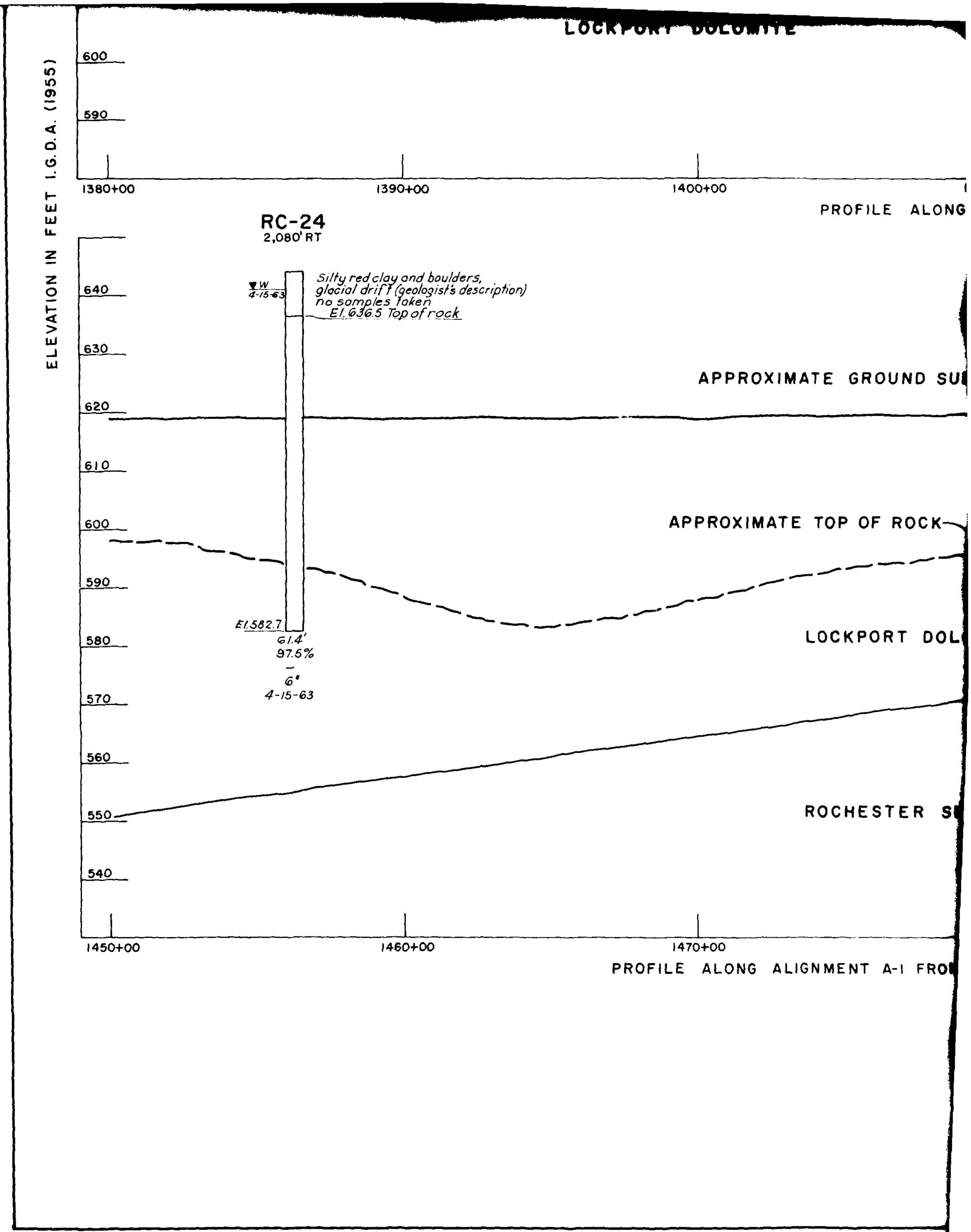


PROFILE ALONG ALIGNMENT A-I FROM STATION 1380+00 TO 1450+00

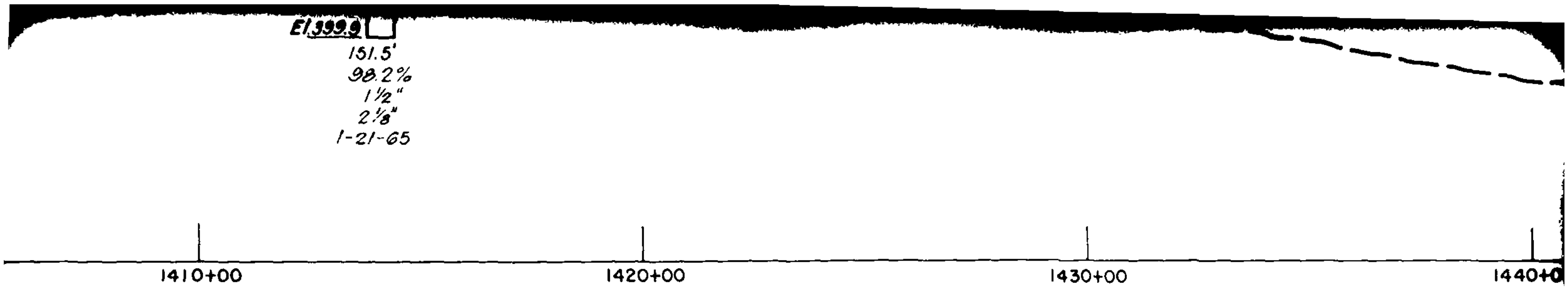



APPROXIMATE TOP OF ROCK
650
640
630
620
610
600
590
1430+0C
1440+00
1450+00

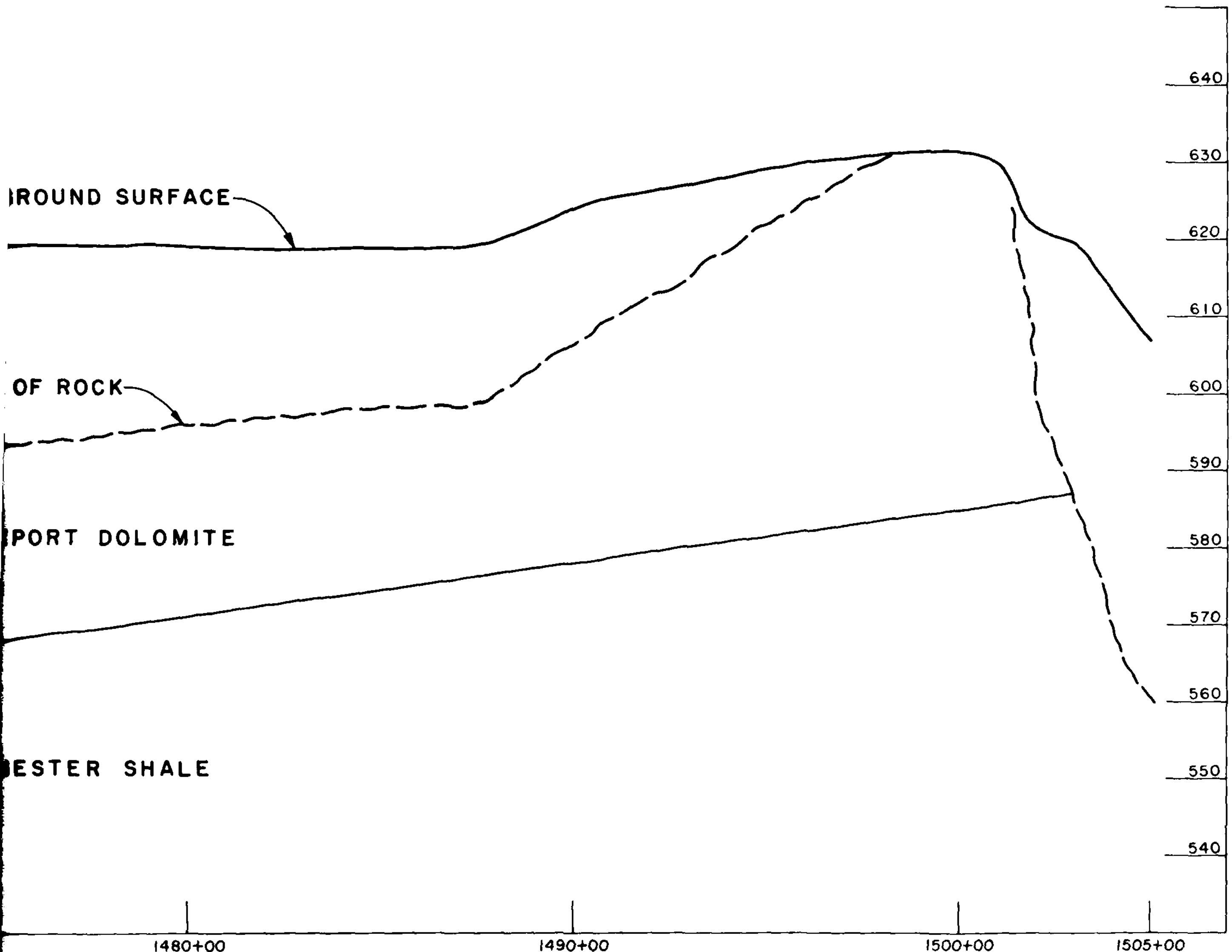

640
630
620
610
600
590
580
570
560
550



LOCKPORT DOLOMITE
ELEVATION IN FEET I.G.D.A. (1955)
600
590
1380+00
1390+00
1400+00
PROFILE ALONG
RC-24
2,080' RT
W
4-15-63
Silty red clay and boulders, glacial drift (geologist's description) no samples taken
El. 636.5 Top of rock
640
630
620
610
600
590
580
570
560
550
540
APPROXIMATE GROUND SU
APPROXIMATE TOP OF ROCK
LOCKPORT DOL
ROCHESTER SH
El. 582.7
61.4'
97.5%
6'
4-15-63
1450+00
1460+00
1470+00
PROFILE ALONG ALIGNMENT A-1 FRO



ILE ALONG ALIGNMENT A-1 FROM STATION 1380+00 TO 1450+00



NT A-1 FROM STATION 1450+00 TO 1505+00

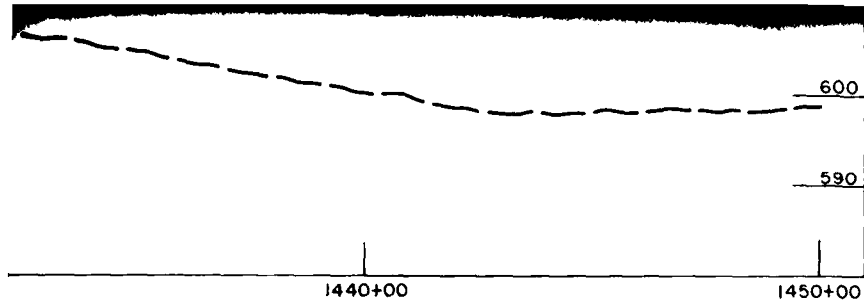
NOTES:

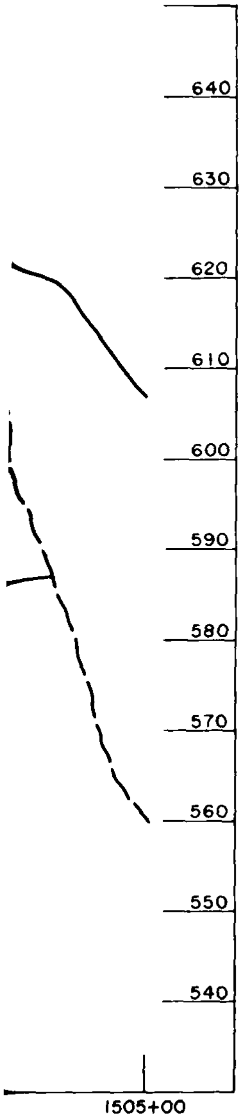
FOR LOCATION OF BORINGS SEE PLATE B3.
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS SEE PLATE B11.

LAK

SOIL P
STATIO

U. S. A
TO AC





LAKE ERIE-LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1380+00 TO 1505+00 ℄ CANAL

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
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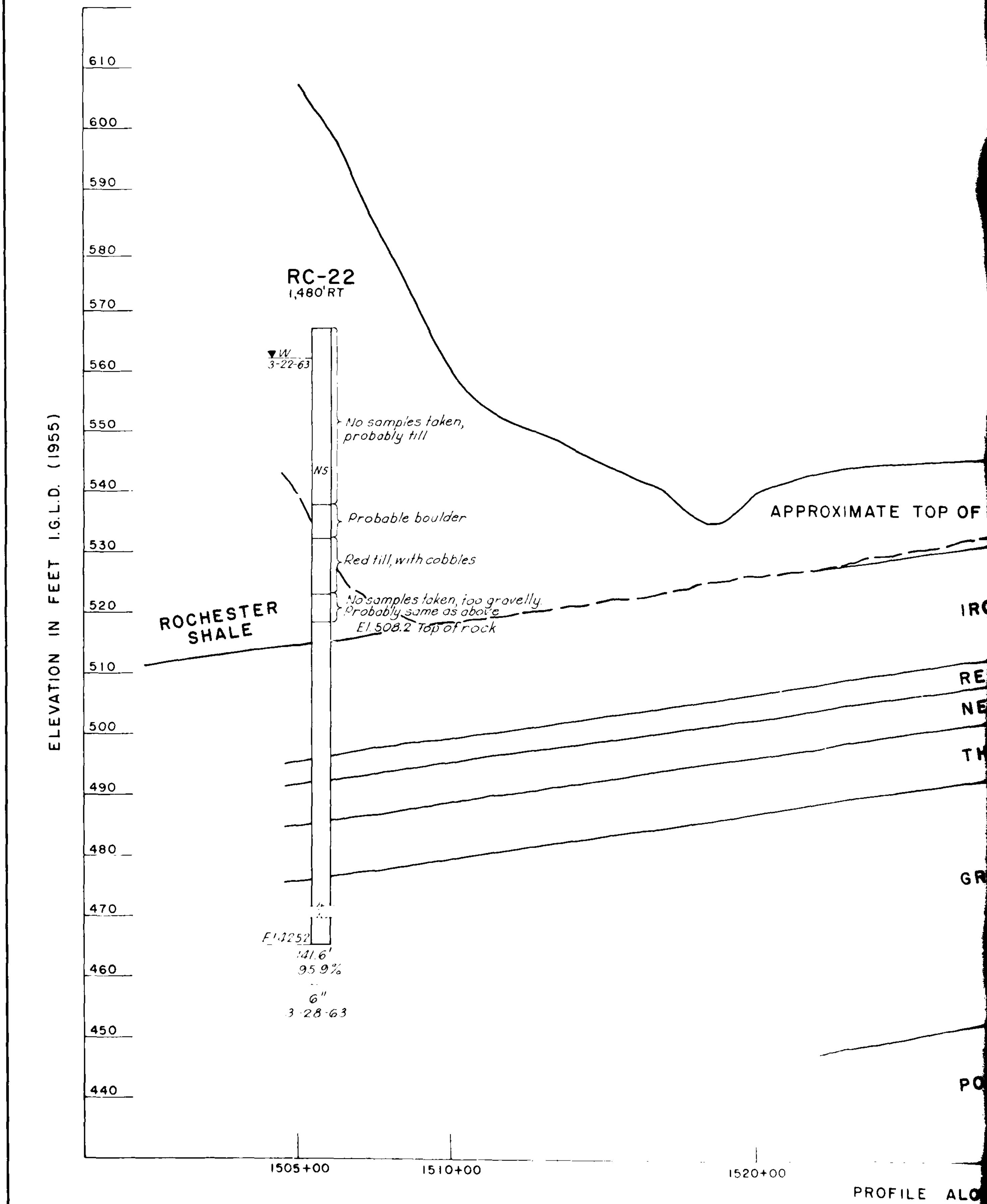
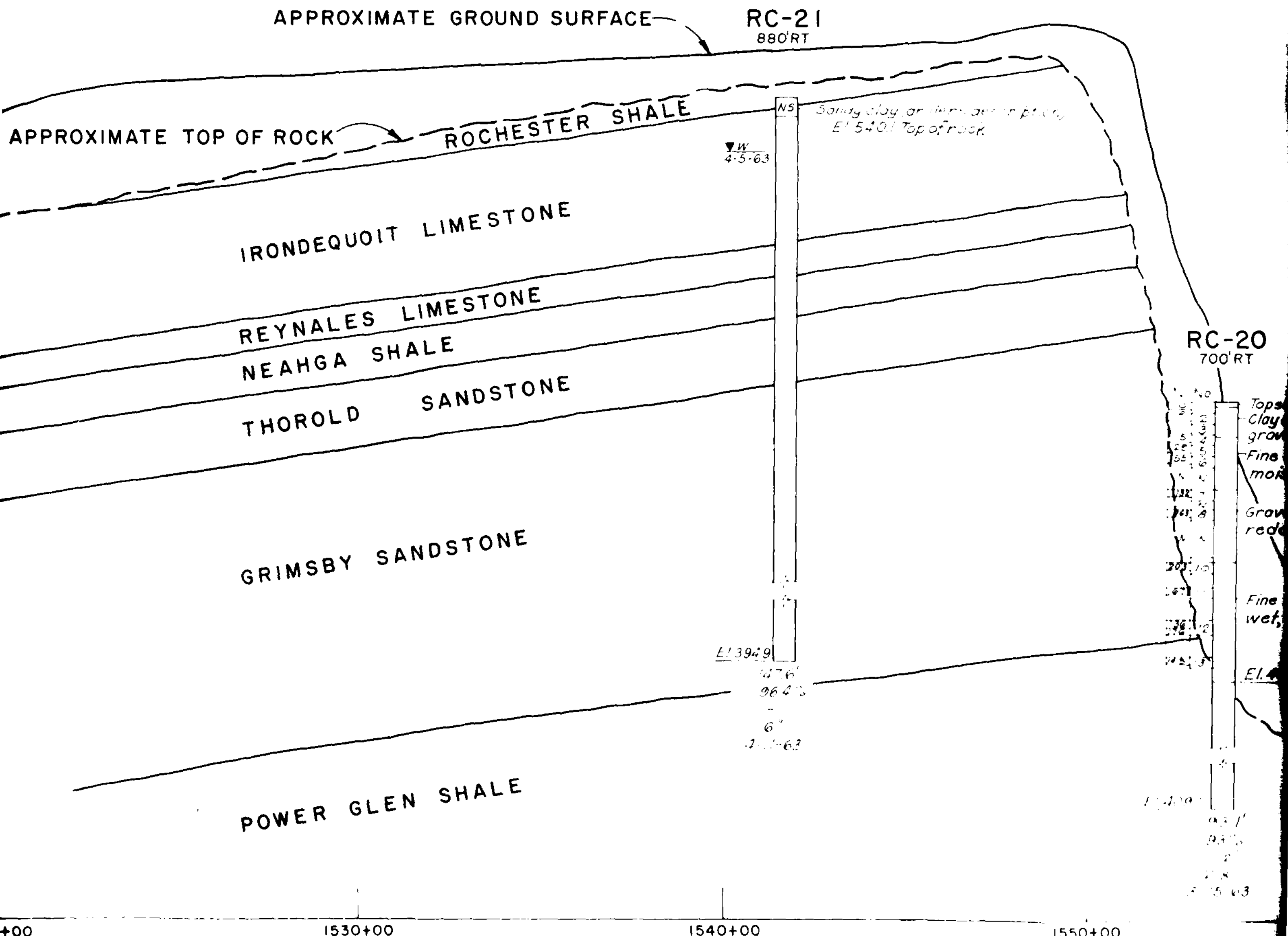
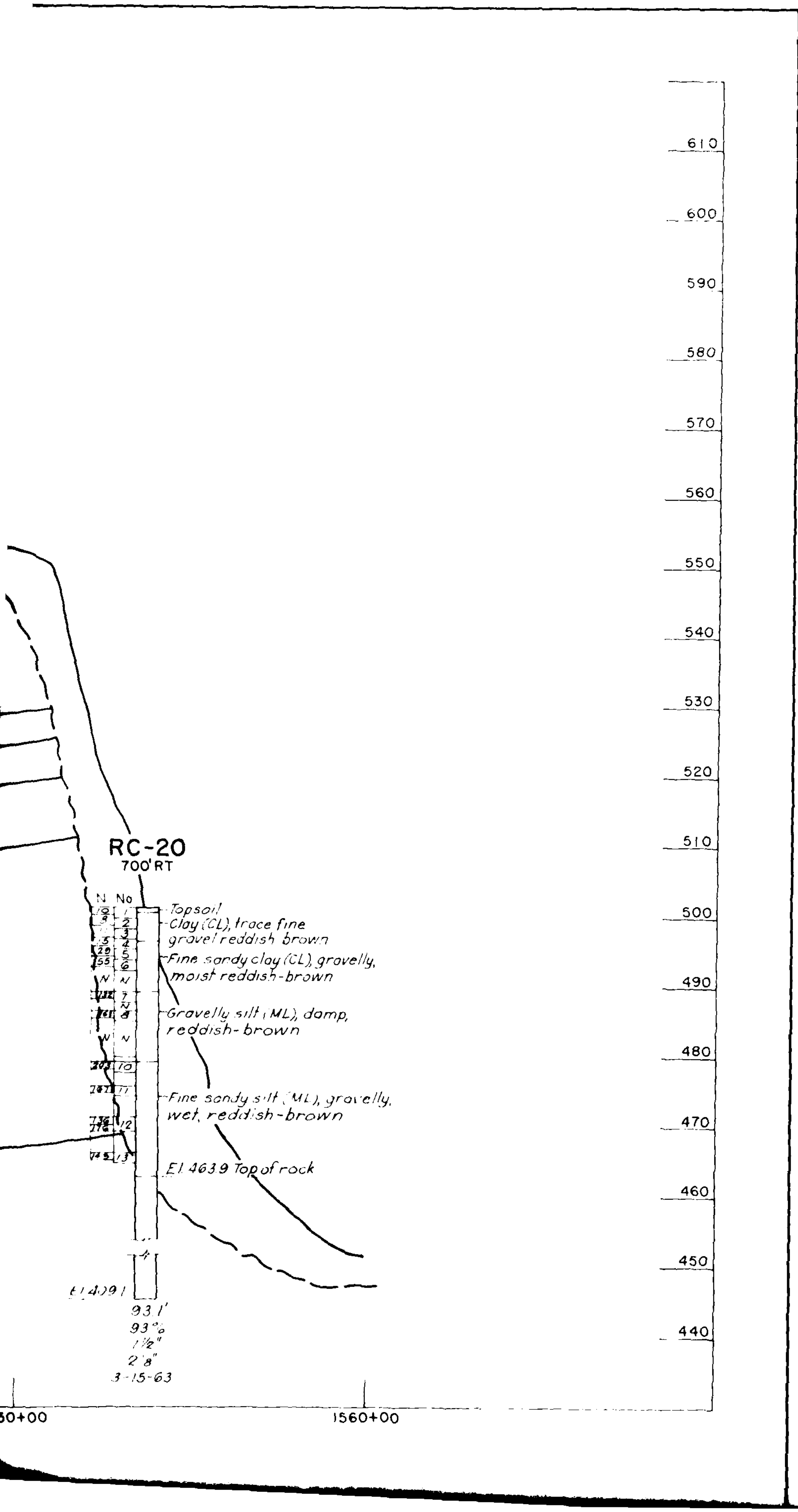
PLATE B13



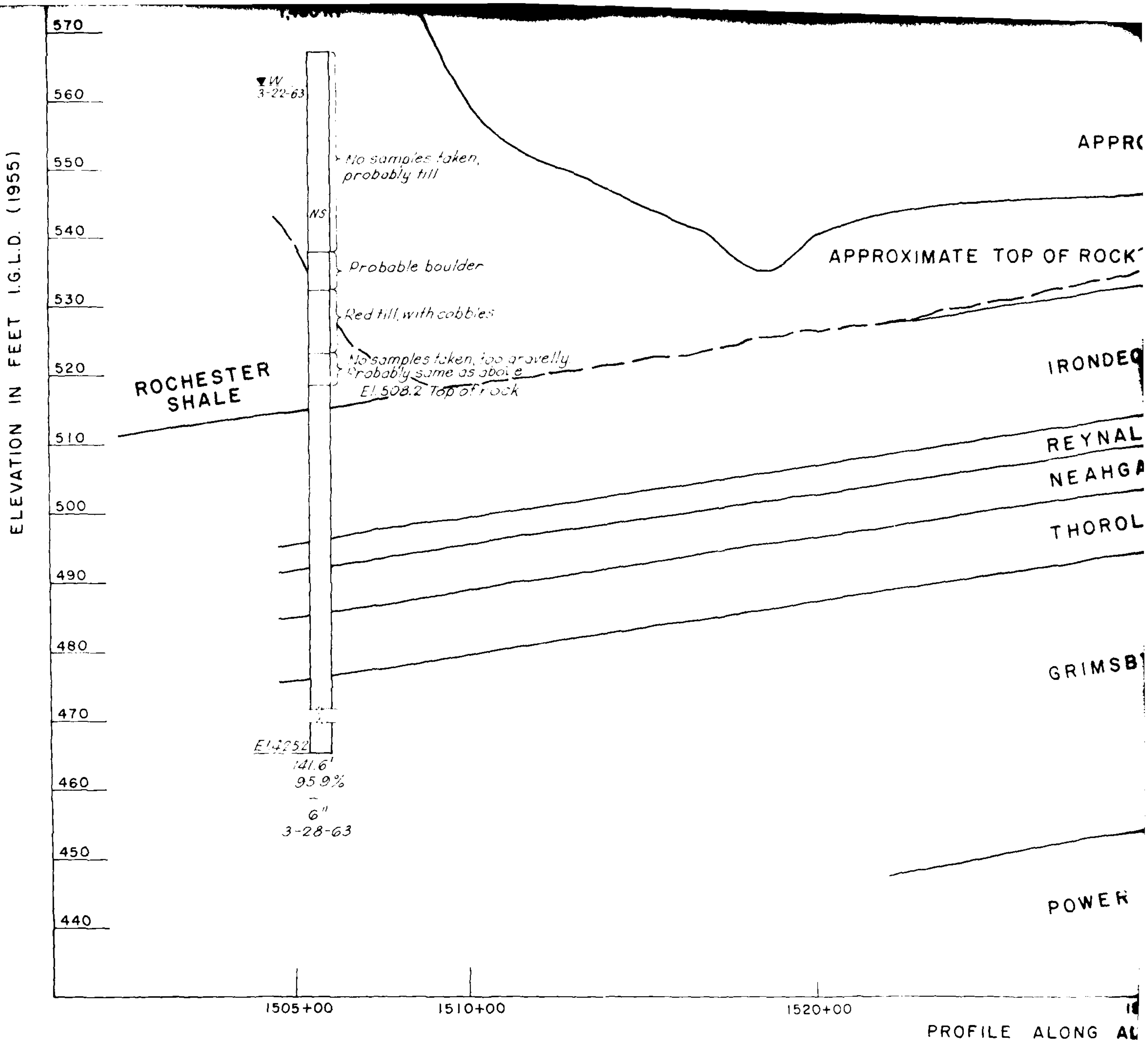
610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
440
ELEVATION IN FEET I.G.L.D. (1955)
RC-22
1,480' RT
W
3-22-63
No samples taken, probably till
NS
Probable boulder
Red till, with cobbles
No samples taken, too gravelly. Probably same as above
El 508.2 Top of rock
ROCHESTER SHALE
APPROXIMATE TOP OF
IR
RE
NE
TH
GR
PO
141.6'
95.9%
6"
3-28-63
1505+00
1510+00
1520+00
PROFILE ALO



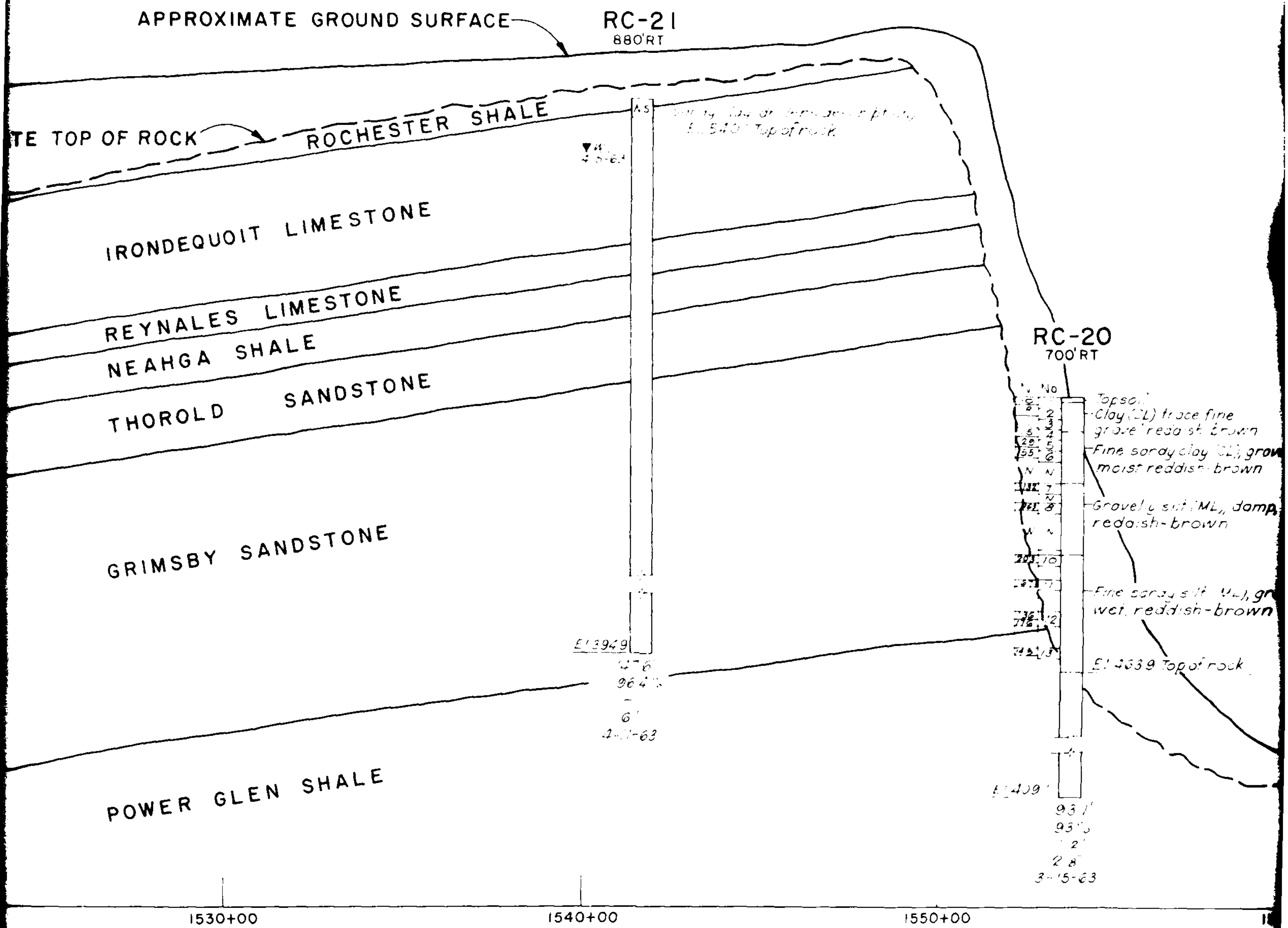
PROFILE ALONG ALIGNMENT A-I FROM STATION 1505+00 TO 1560+00



610
600
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
440
RC-20
700'RT
N
No
Topsoil
Clay (CL), trace fine gravel reddish brown
Fine sandy clay (CL), gravelly, moist reddish-brown
Gravelly silt (ML), damp, reddish-brown
Fine sandy silt (ML), gravelly, wet, reddish-brown
El. 463.9 Top of rock
El. 409.1
93.1'
93%
1½"
2'8"
3-15-63
1560+00



ELEVATION IN FEET I.G.L.D. (1955)
570
560
550
540
530
520
510
500
490
480
470
460
450
440
W
3-22-63
No samples taken, probably till
NS
Probable boulder
Red till, with cobbles
No samples taken, too gravelly
Probably same as above
El. 508.2 Top of rock
El. 425.2
141.6'
95.9%
6"
3-28-63
ROCHESTER SHALE
APPROXIMATE TOP OF ROCK
IRONDEQ
REYNAL
NEAHGA
THOROL
GRIMSB
POWER
1505+00
1510+00
1520+00
PROFILE ALONG



OFILE ALONG ALIGNMENT A-1 FROM STATION 1505+00 TO 1560+00

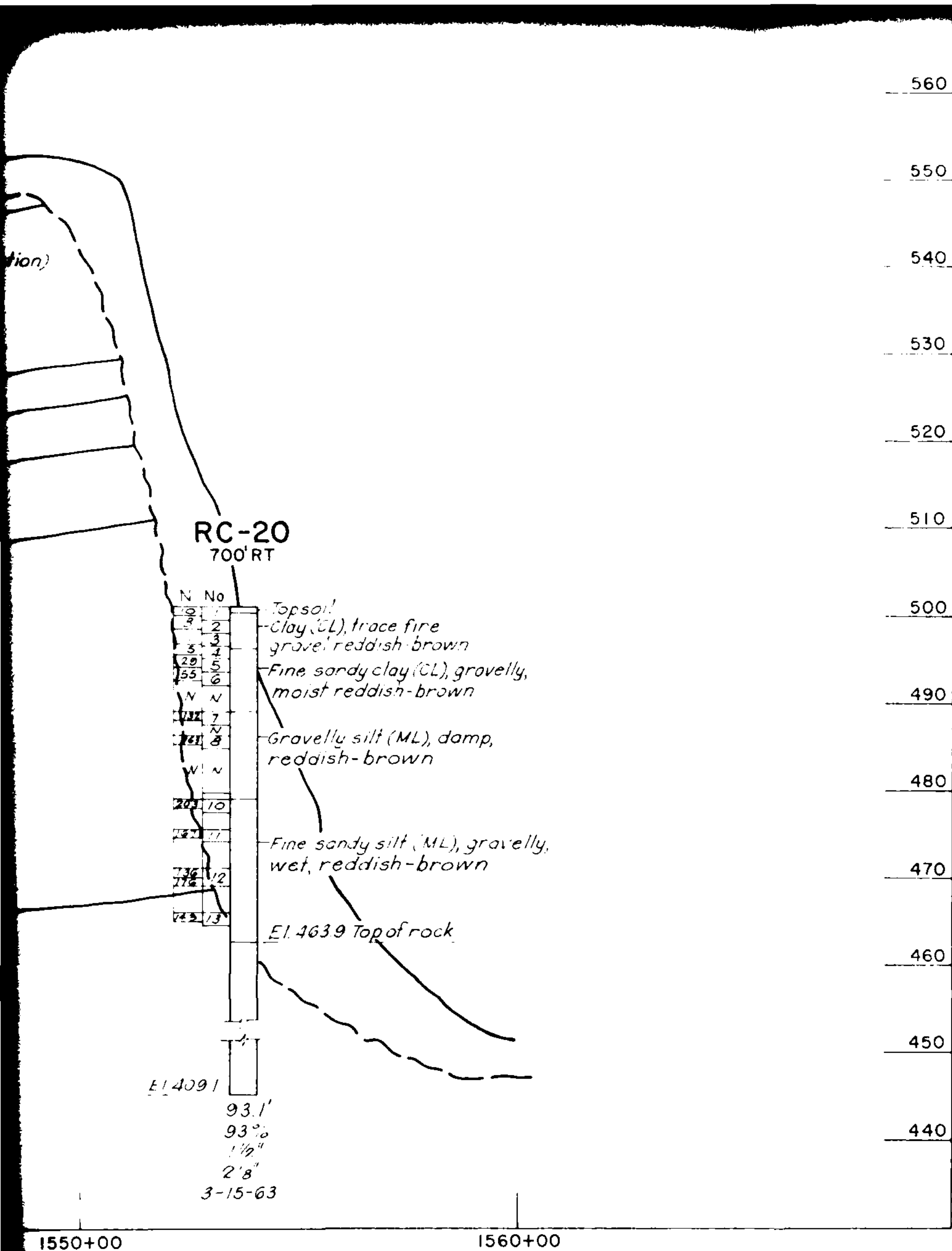
NOTES:

FOR LOCATION OF BORINGS SEE PLATES B3 AND B4.
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS SEE PLATE B11.

LAK

SOIL PR
STATIO

U.S. AR



LAKE ERIE-LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1505+00 TO 1560+00 ℄ CANAL

U.S. ARMY ENGINEER DISTRICT, BUFFALO

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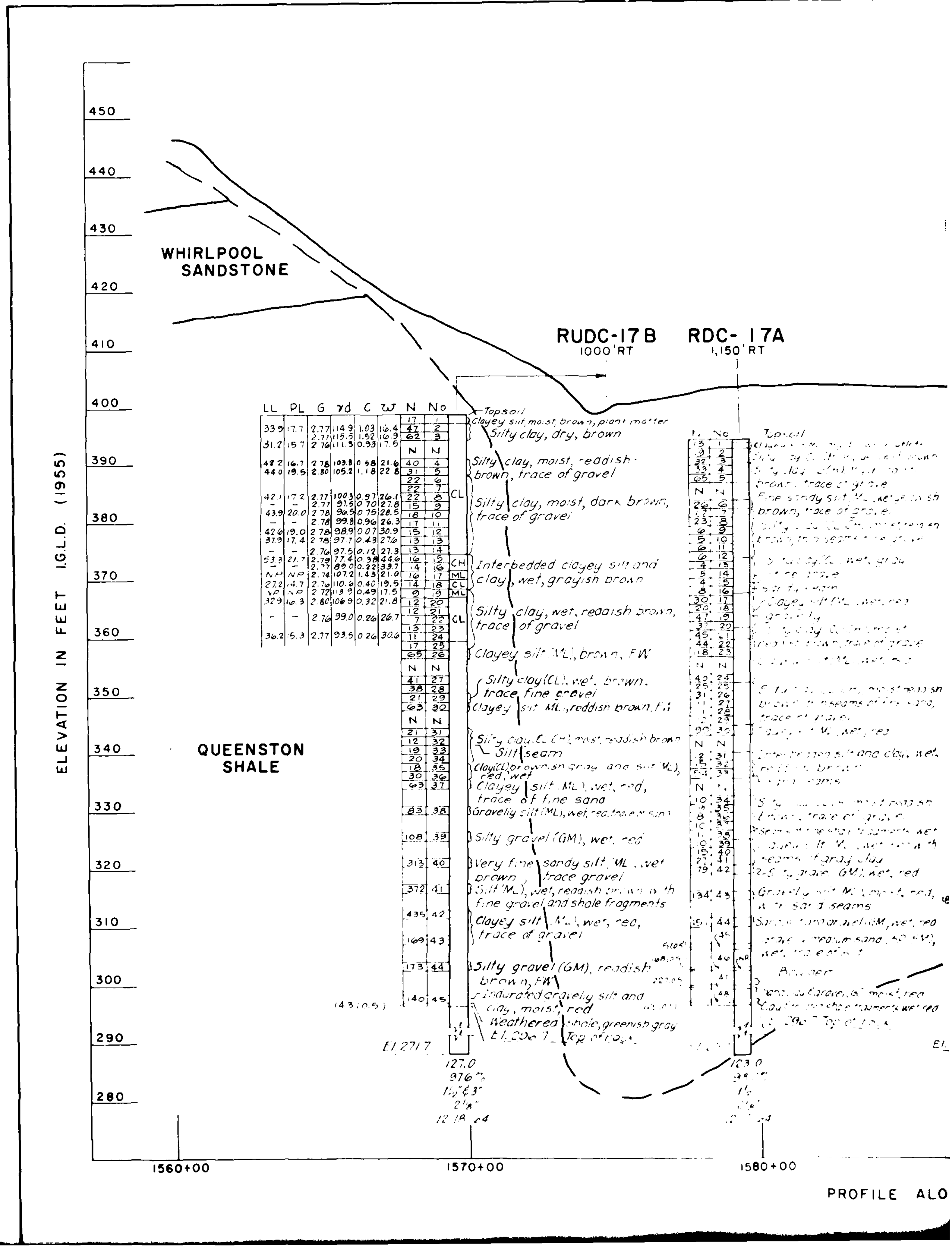
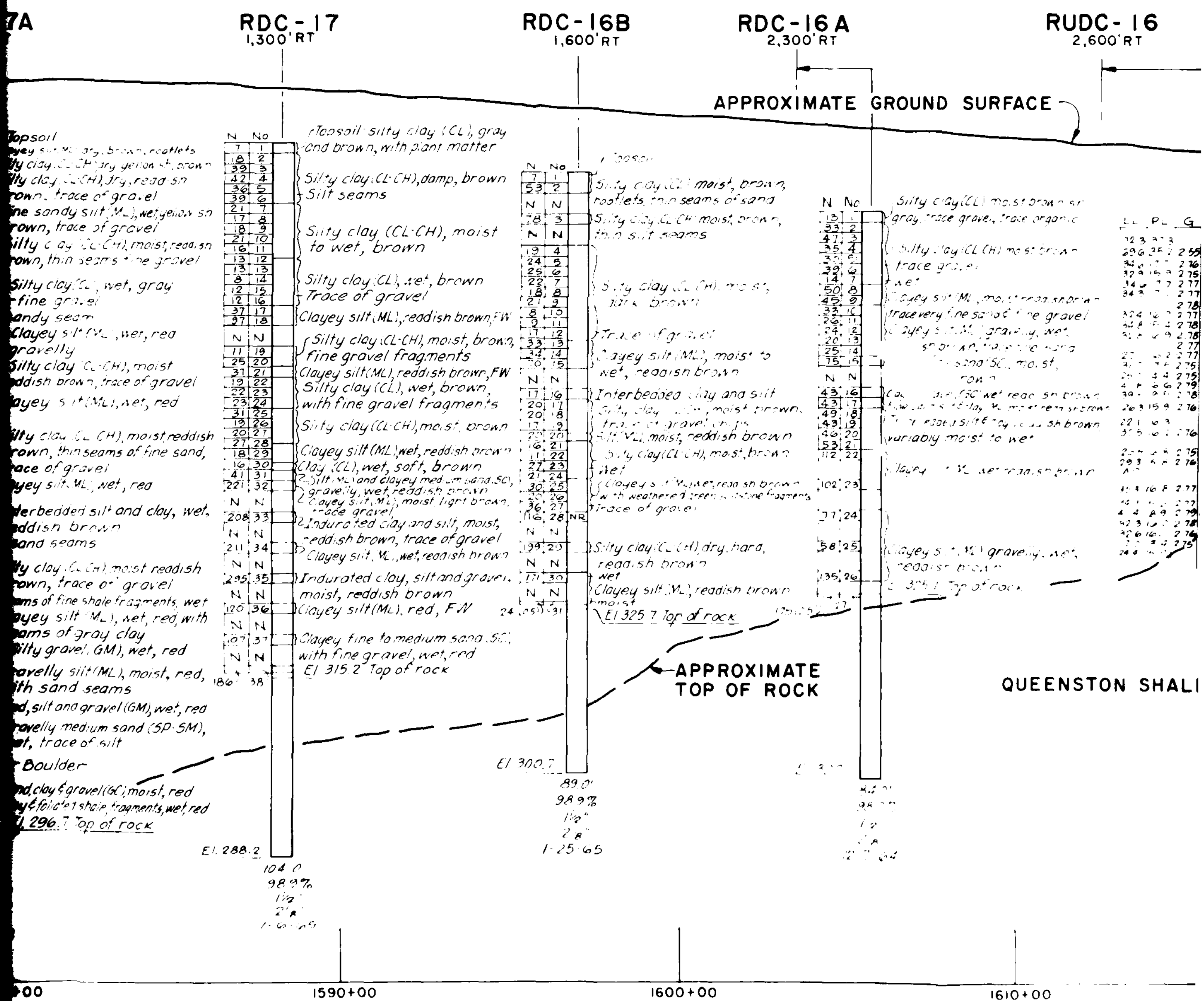
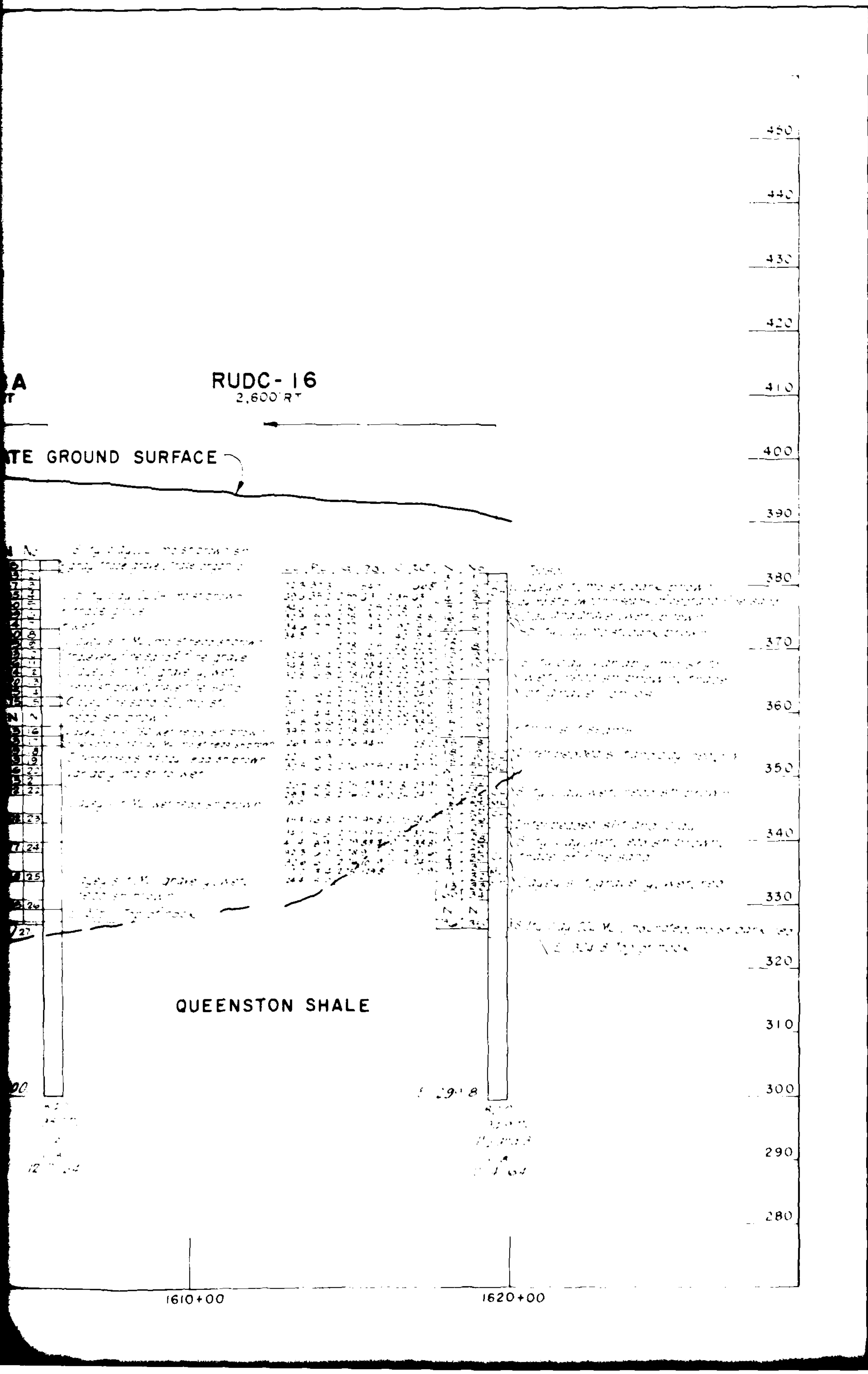
PLATE B14

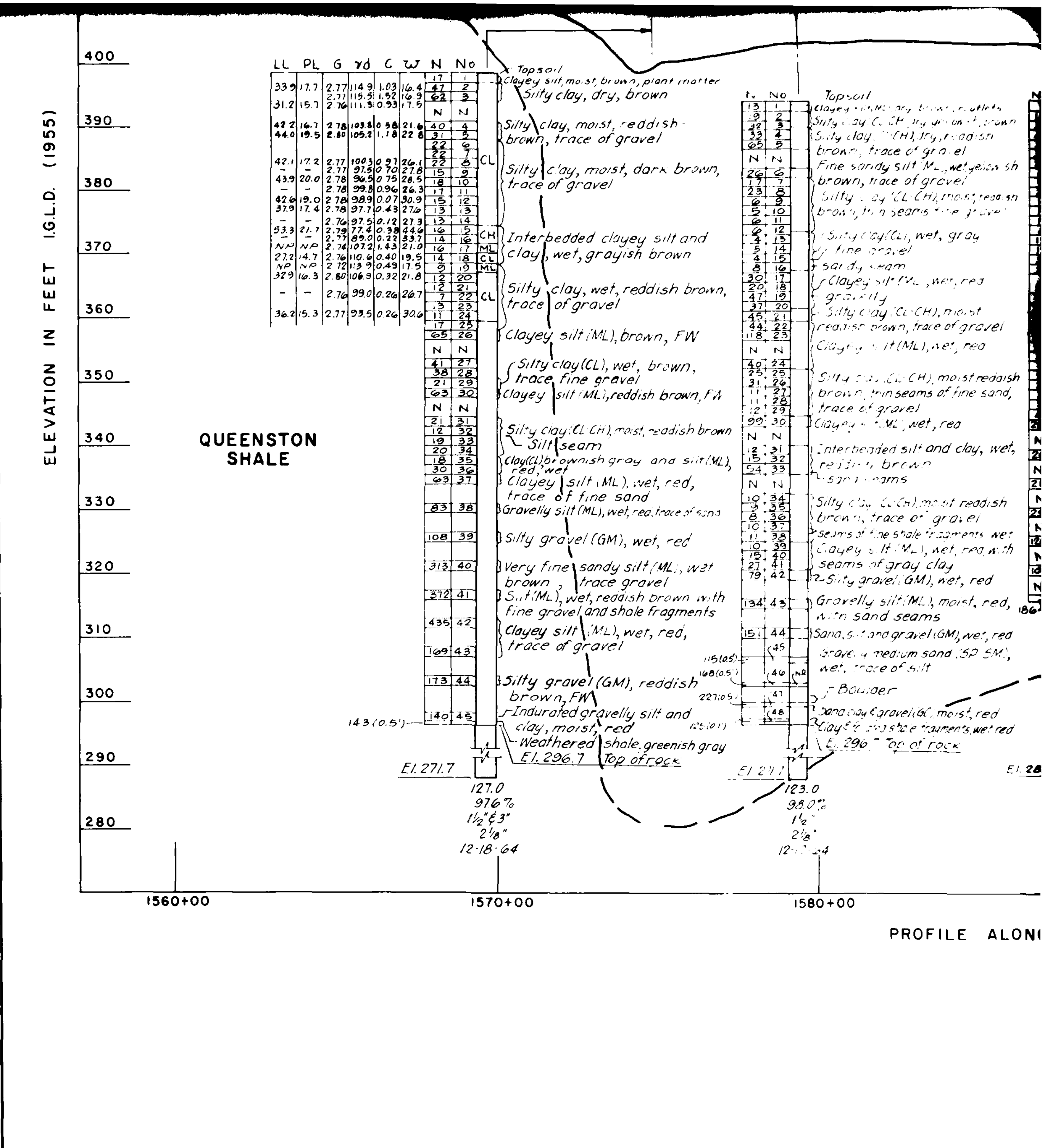

ELEVATION IN FEET I.G.L.D. (1955)
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
WHIRLPOOL SANDSTONE
QUEENSTON SHALE
RUDC-17B
1000'RT
RDC- 17A
1,150'RT
LL PL G γd C ω N No
Topsoil
Clayey silt, moist, brown, plant matter
Silty clay, dry, brown
Silty clay, moist, reddish-brown, trace of gravel
Silty clay, moist, dark brown, trace of gravel
Interbedded clayey silt and clay, wet, grayish brown
Silty clay, wet, reddish brown, trace of gravel
Clayey silt (ML), brown, FW
Silty clay (CL), wet, brown, trace fine gravel
Clayey silt ML, reddish brown, FW
Silt seam
Clayey silt ML, wet, red, trace of fine sand
Gravelly silt (ML), wet, red
Silty gravel (GM), wet, red
Very fine sandy silt ML, wet brown, trace gravel
Silt (ML), wet, reddish brown with fine gravel and shale fragments
Clayey silt ML, wet, red, trace of gravel
Silty gravel (GM), reddish brown, FW
Indurated gravelly silt and clay, moist, red
Weathered shale, greenish gray
Top of rock
El. 271.7
127.0
Boulder
1560+00
1570+00
1580+00
PROFILE ALO

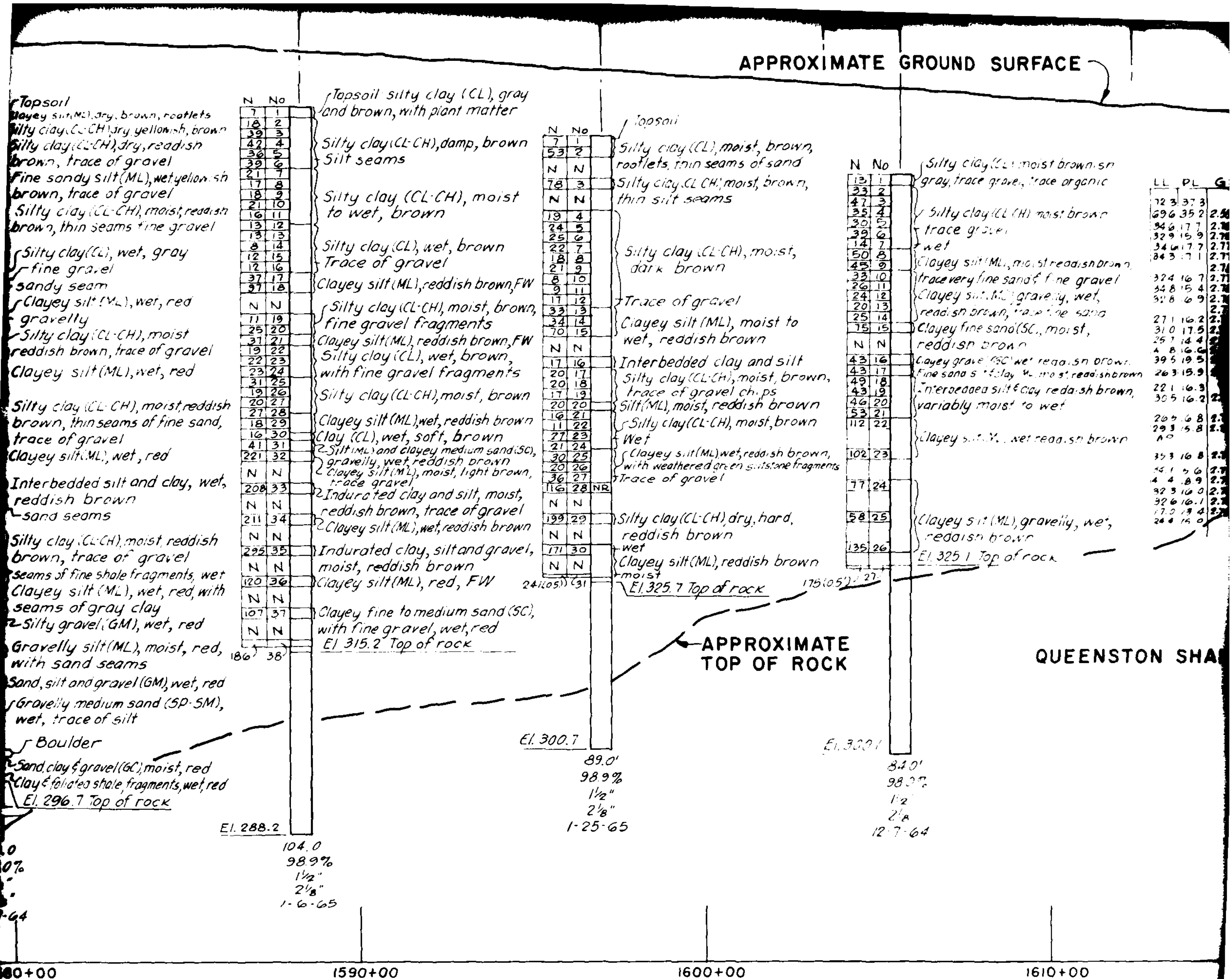


PROFILE ALONG ALIGNMENT A-1 FROM STATION 1560+00 TO 1620+00



RUDC-16
2,600' RT
TE GROUND SURFACE
QUEENSTON SHALE
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
1610+00
1620+00

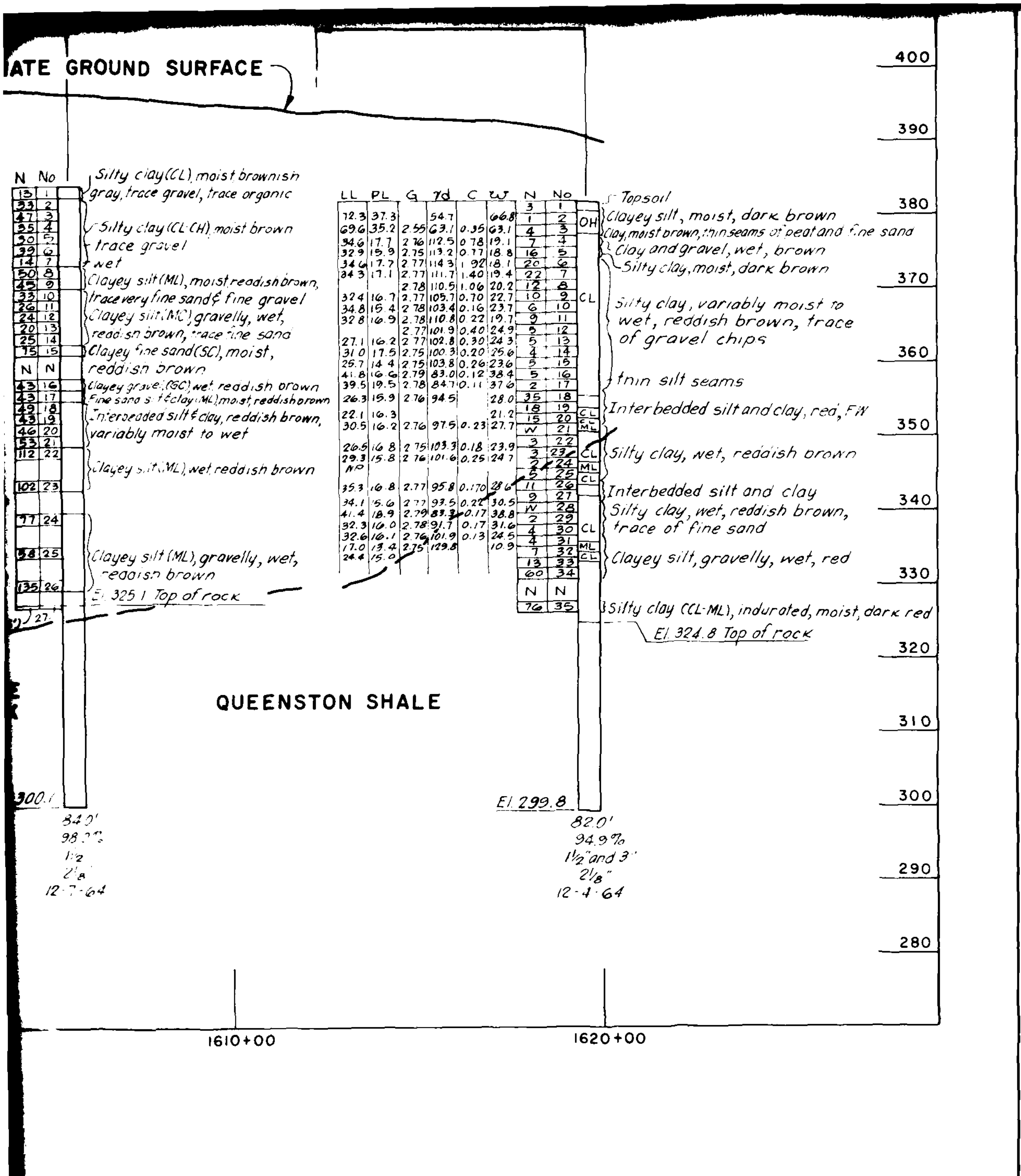

ELEVATION IN FEET I.G.L.D. (1955)
400
390
380
370
360
350
340
330
320
310
300
290
280
LL PL G γd C W N No
QUEENSTON SHALE
Topsoil
Silty clay, dry, brown
Silty clay, moist, reddish-brown, trace of gravel
Silty clay, moist, dark brown, trace of gravel
Interbedded clayey silt and clay, wet, grayish brown
Silty clay, wet, reddish brown, trace of gravel
Clayey silt (ML), brown, FW
Silty clay (CL), wet, brown, trace fine gravel
Clayey silt (ML), reddish brown, FW
Silty clay (CL CH), moist, reddish brown
Silt seam
Clayey silt (ML), wet, red, trace of fine sand
Gravelly silt (ML), wet, red, trace of sand
Silty gravel (GM), wet, red
Very fine sandy silt (ML), wet brown, trace gravel
Clayey silt (ML), wet, red, trace of gravel
Silty gravel (GM), reddish brown, FW
Indurated gravelly silt and clay, moist, red
Weathered shale, greenish gray
El. 296.7 Top of rock
El. 271.7
127.0
97.6%
1½" & 3"
2⅛"
12-18-64
Topsoil
Silty clay (CL-CH), moist, reddish brown, thin seams of fine sand, trace of gravel
Interbedded silt and clay, wet, reddish brown
Gravelly silt (ML), moist, red, with sand seams
Silty gravel (GM), wet, red
Boulder
El. 296.7 Top of rock
123.0
98.0%
1½"
2⅛"
1560+00
1570+00
1580+00
PROFILE ALON



PROFILE ALONG ALIGNMENT A-1 FROM STATION 1560+00 TO 1620+00

NOTES:

FOR LOCATION OF BORINGS SEE PLATE B4.
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS SEE PLATE B11.



SEE PLATE B4.
LES AND NOTES
TE B11.

LAKE ERIE–LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1560+00 TO 1620+00 ℄ CANAL

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
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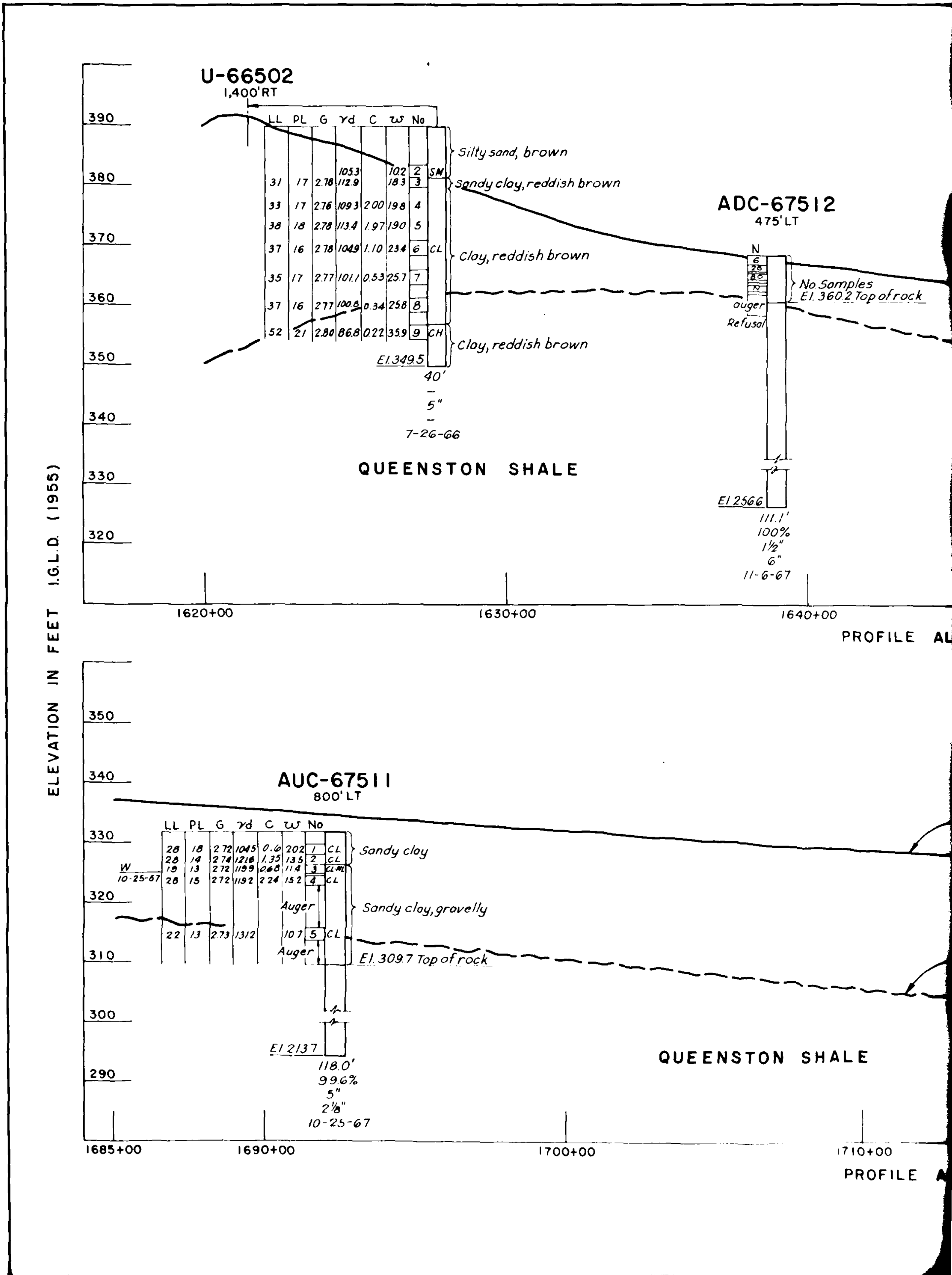
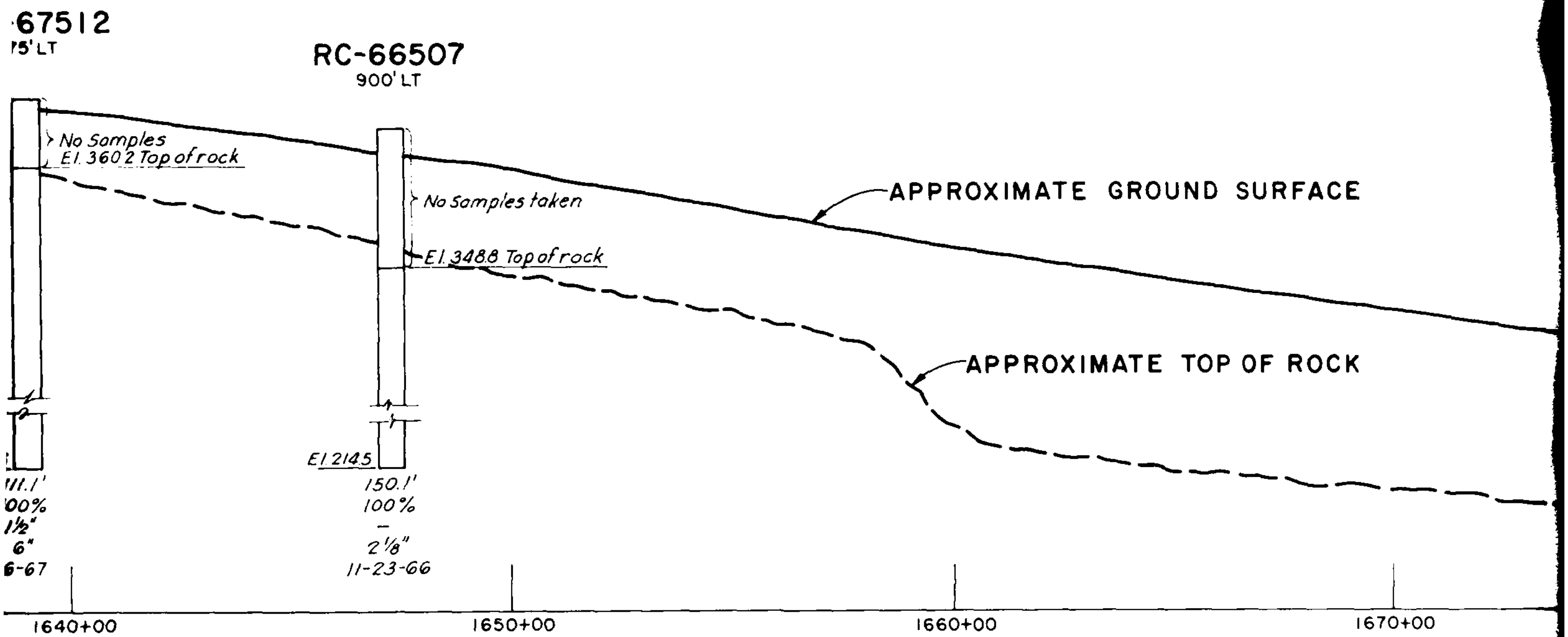
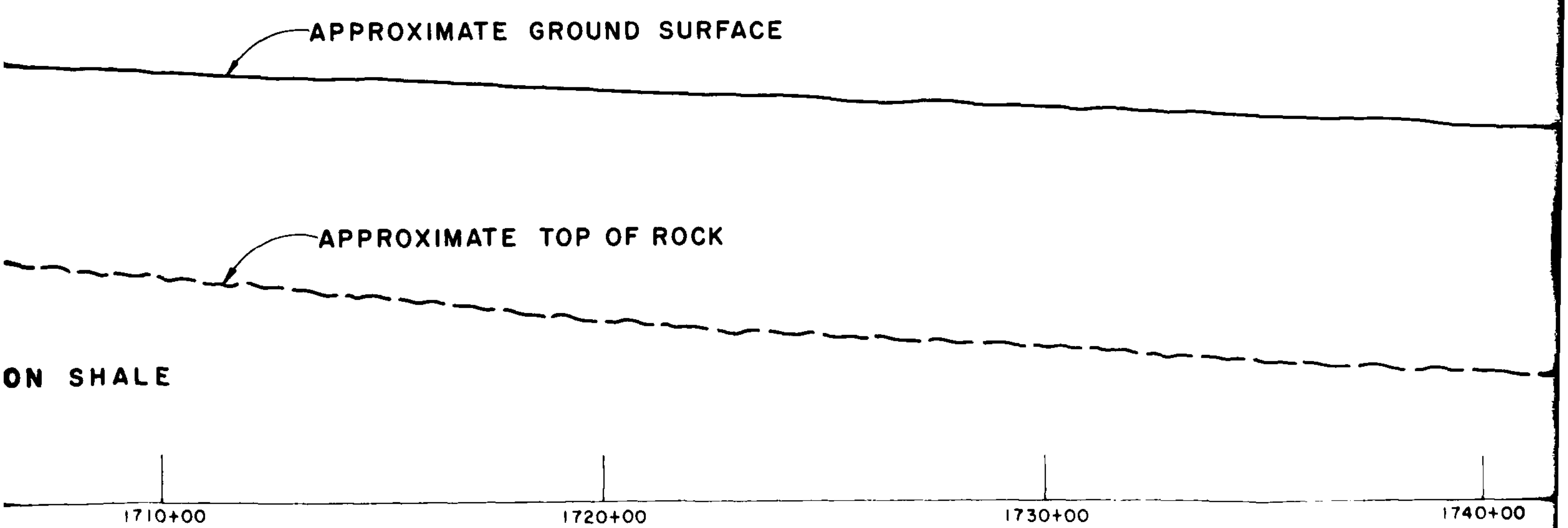
PLATE B15



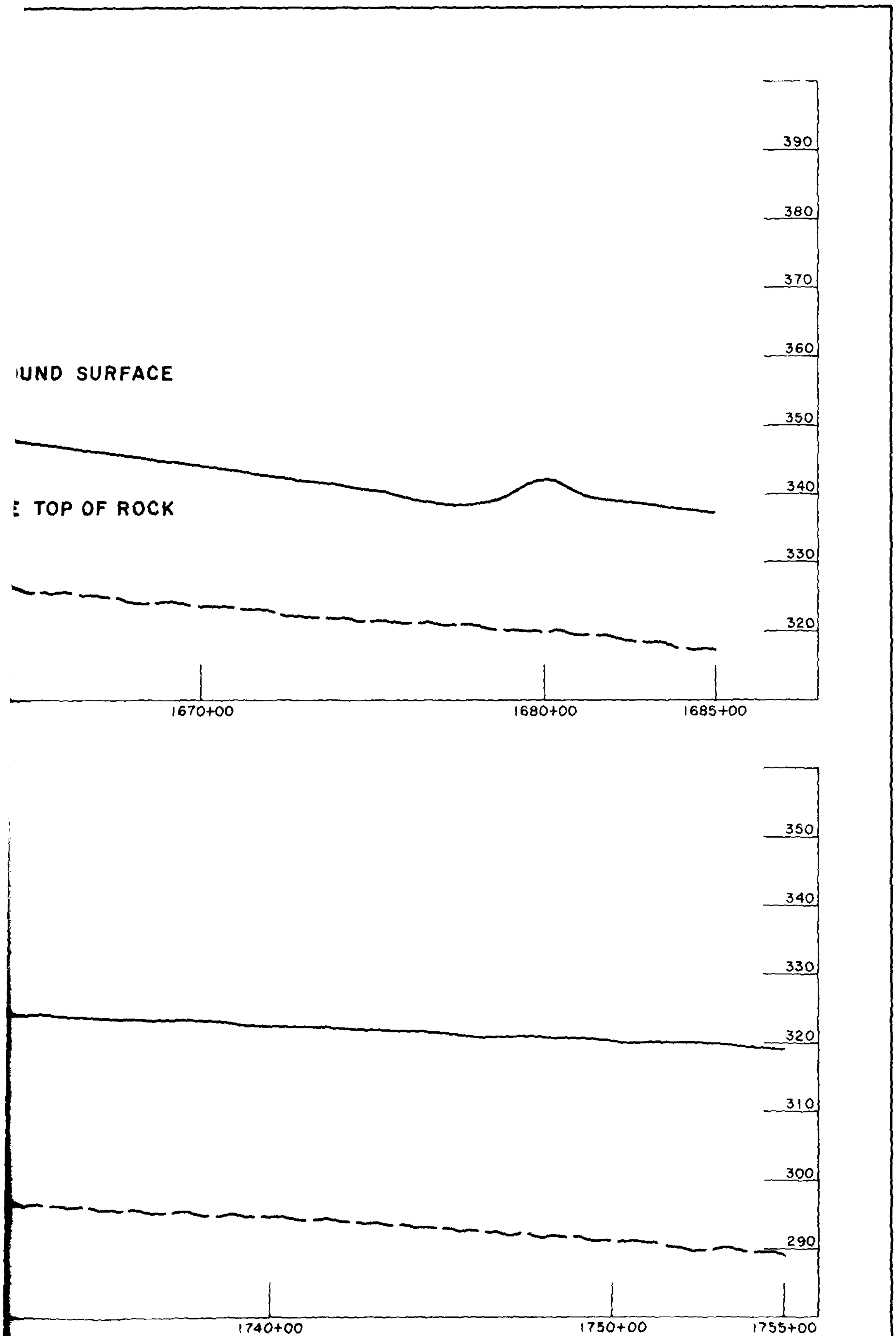
ELEVATION IN FEET I.G.L.D. (1955)
U-66502
1,400' RT
LL PL G γd C w No
Silty sand, brown
Sandy clay, reddish brown
Clay, reddish brown
Clay, reddish brown
SM
CL
CH
El. 349.5
40'
5"
7-26-66
ADC-67512
475' LT
N
No Samples
El. 360.2 Top of rock
auger
Refusal
El. 256.6
111.1'
100%
1½"
6"
11-6-67
QUEENSTON SHALE
1620+00
1630+00
1640+00
PROFILE AL
AUC-67511
800' LT
LL PL G γd C w No
Sandy clay
Sandy clay, gravelly
W
10-25-67
Auger
Auger
El. 309.7 Top of rock
El. 213.7
118.0'
99.6%
5"
2⅛"
10-25-67
QUEENSTON SHALE
1685+00
1690+00
1700+00
1710+00
PROFILE A



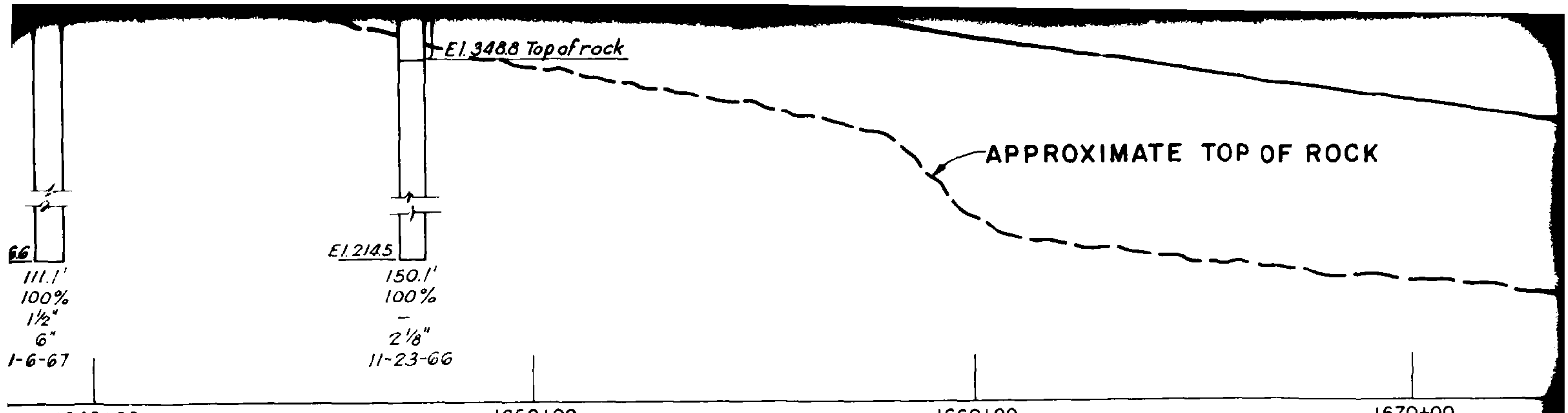
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1620+00 TO 1685+00



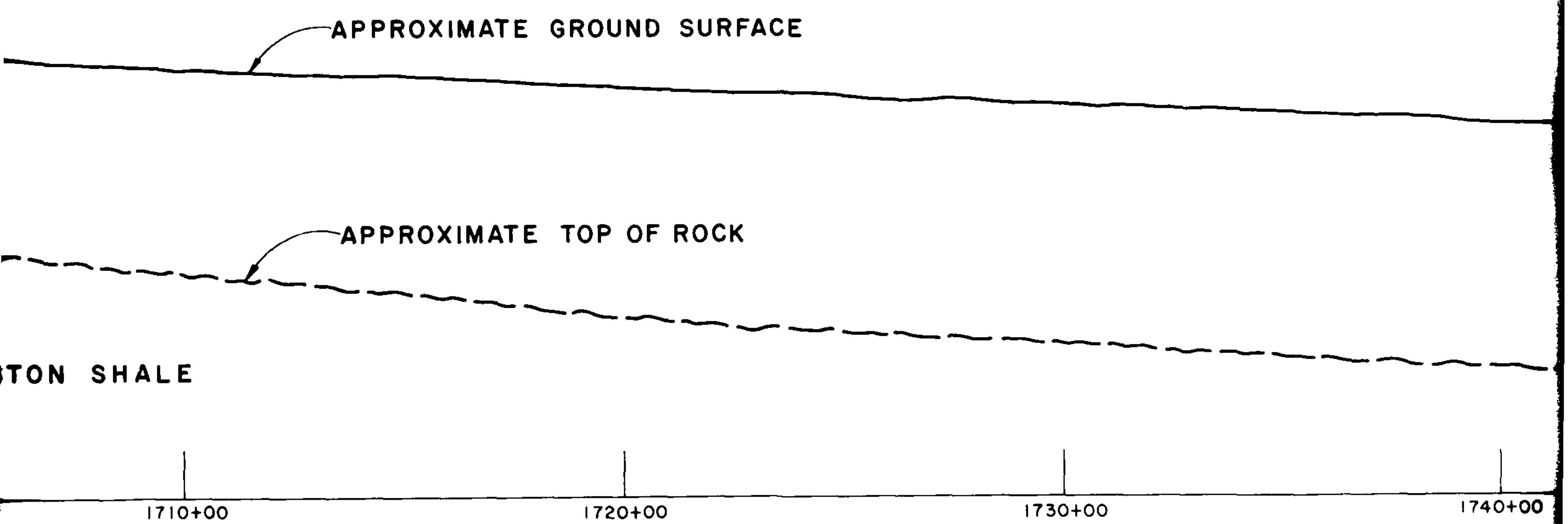
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1685+00 TO 1755+00



UND SURFACE
E TOP OF ROCK
390
380
370
360
350
340
330
320
1670+00
1680+00
1685+00
350
340
330
320
310
300
290
1740+00
1750+00
1755+00



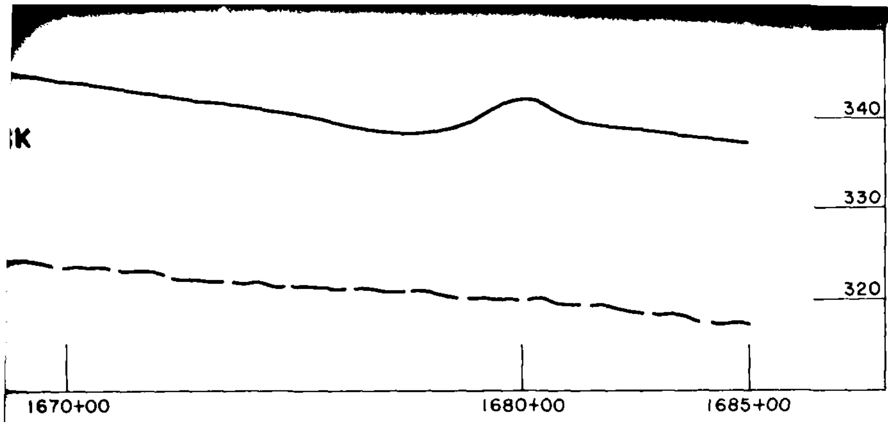
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1620+00 TO 1685+00

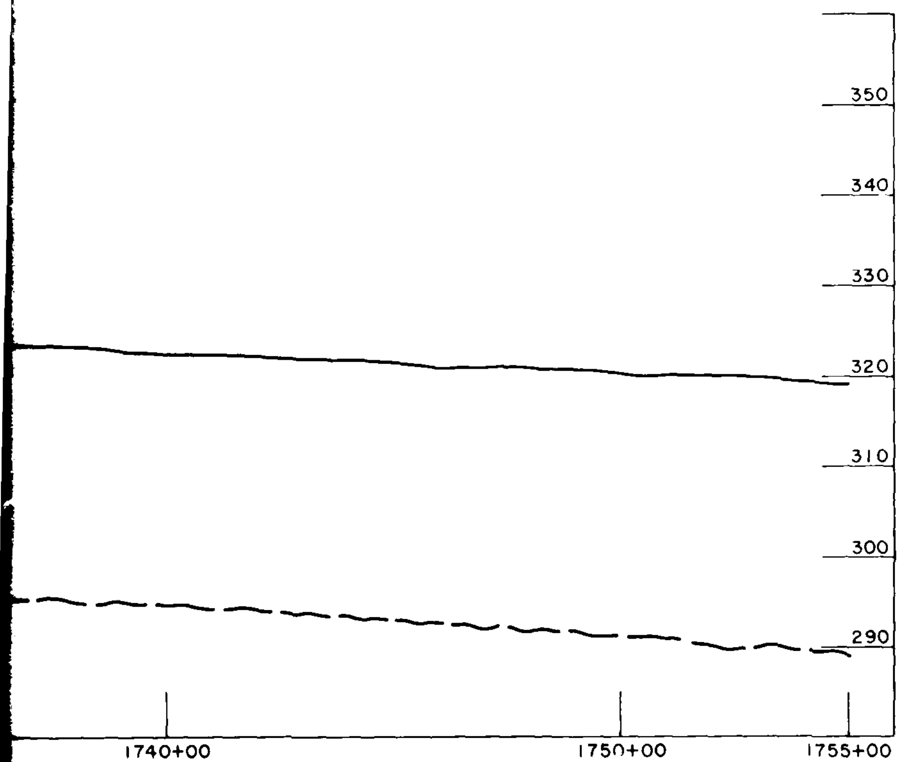


PROFILE ALONG ALIGNMENT A-1 FROM STATION 1685+00 TO 1755+00

NOTES:

FOR LOCATION OF BORINGS SEE PLATE B4.
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS SEE PLATE B11.





LAKE ERIE–LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1620+00 TO 1755+00 ℄ CANAL

U.S. ARMY ENGINEER DISTRICT, BUFFALO

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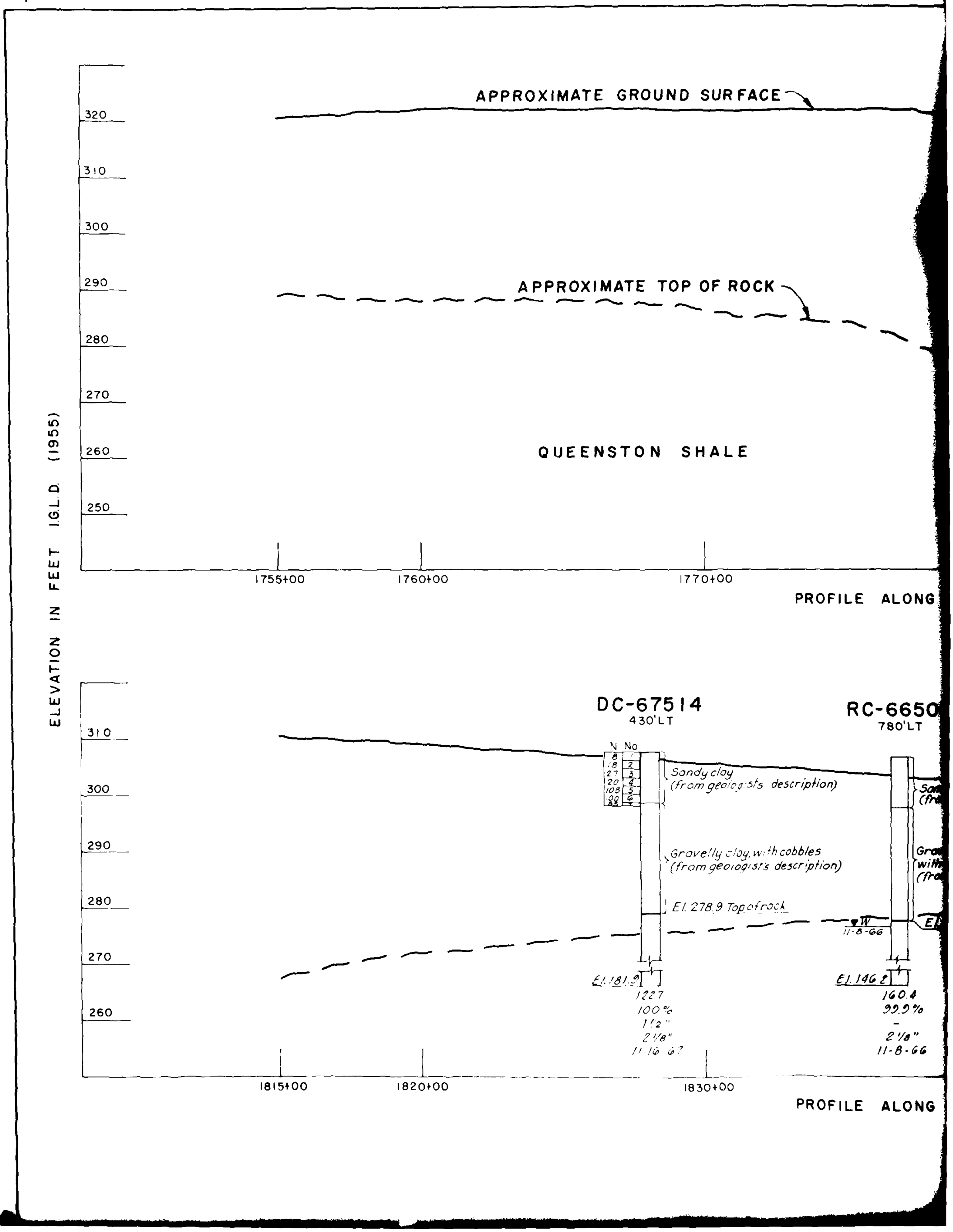
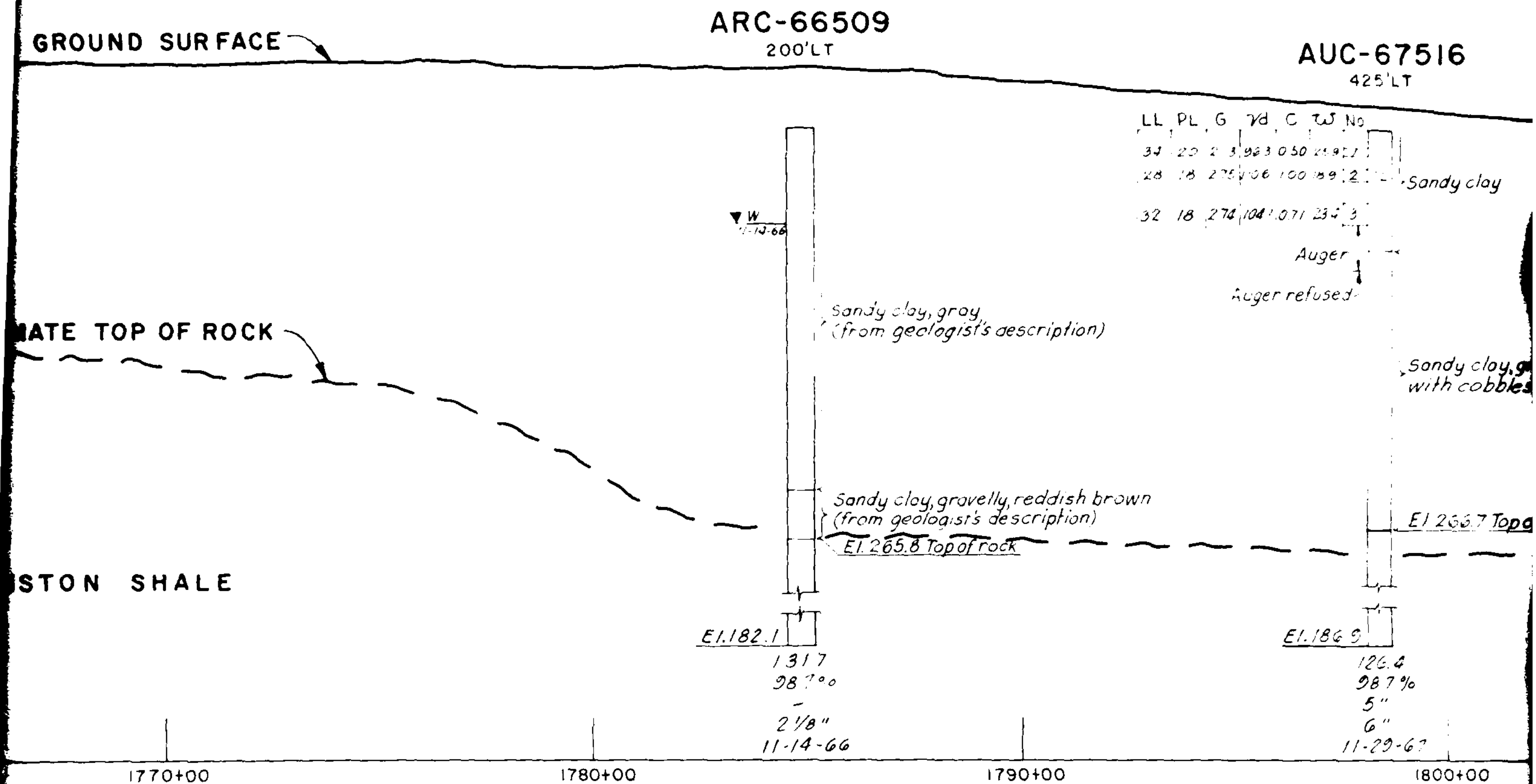
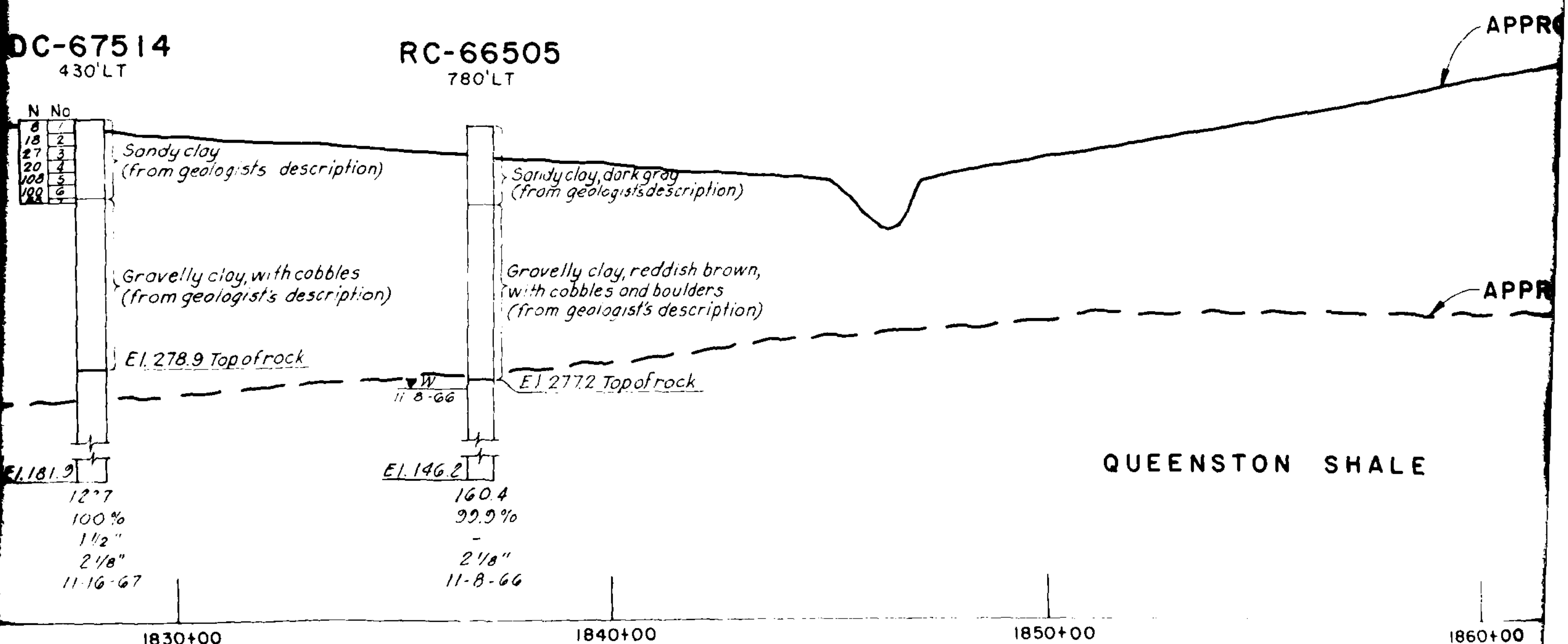
PLATE B16



ELEVATION IN FEET I.G.L.D. (1955)
APPROXIMATE GROUND SURFACE
APPROXIMATE TOP OF ROCK
QUEENSTON SHALE
320
310
300
290
280
270
260
250
1755+00
1760+00
1770+00
PROFILE ALONG
DC-67514
430'LT
RC-6650
780'LT
N No
Sandy clay
(from geologists description)
Gravelly clay, with cobbles
(from geologist's description)
El. 278.9 Top of rock
11-8-66
El. 181.9
122.7
100 %
1 1/2"
2 1/8"
11-16-67
El. 146.2
160.4
99.9 %
-
2 1/8"
11-8-66
1815+00
1820+00
1830+00
PROFILE ALONG



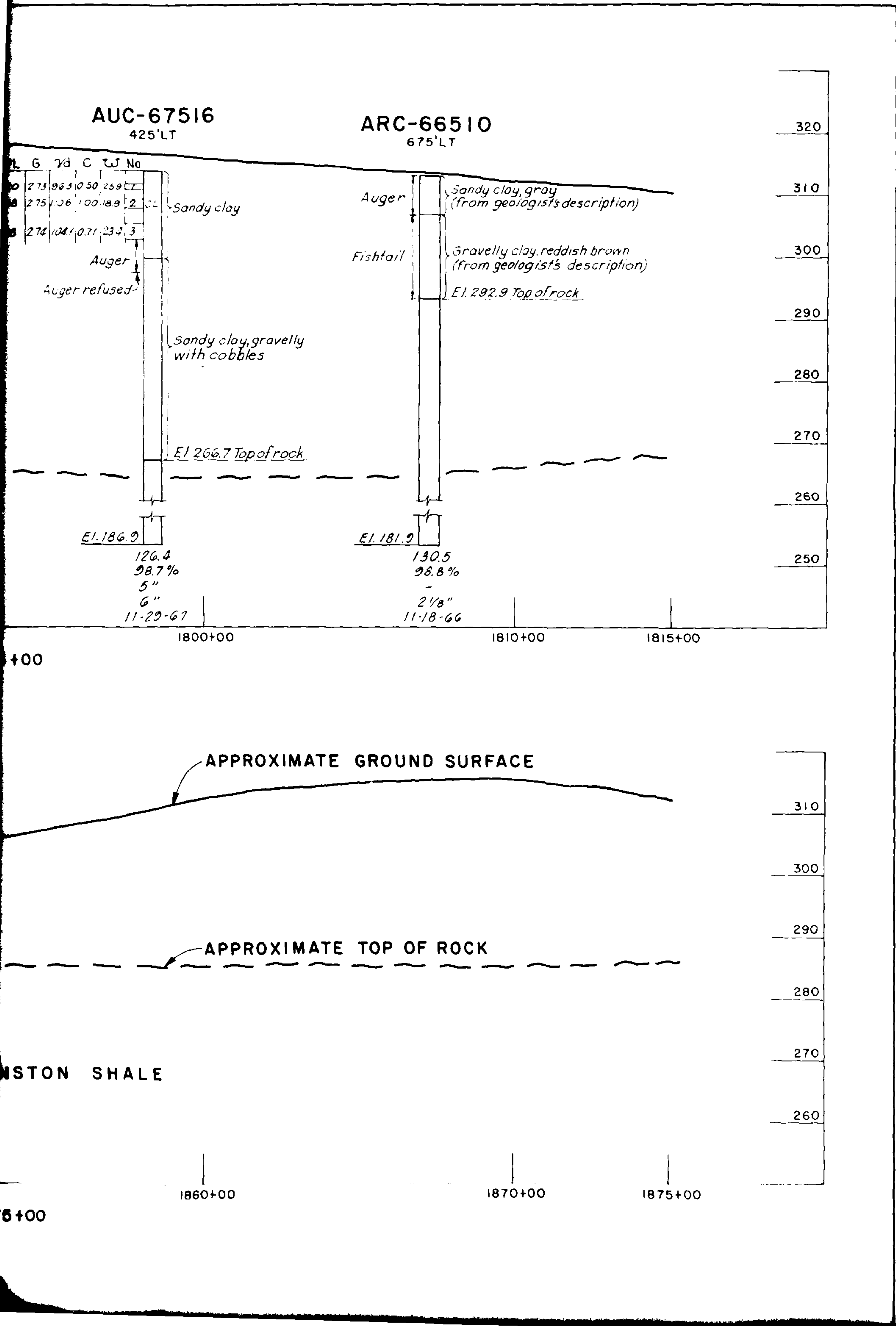
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1755+00 TO 1815+00

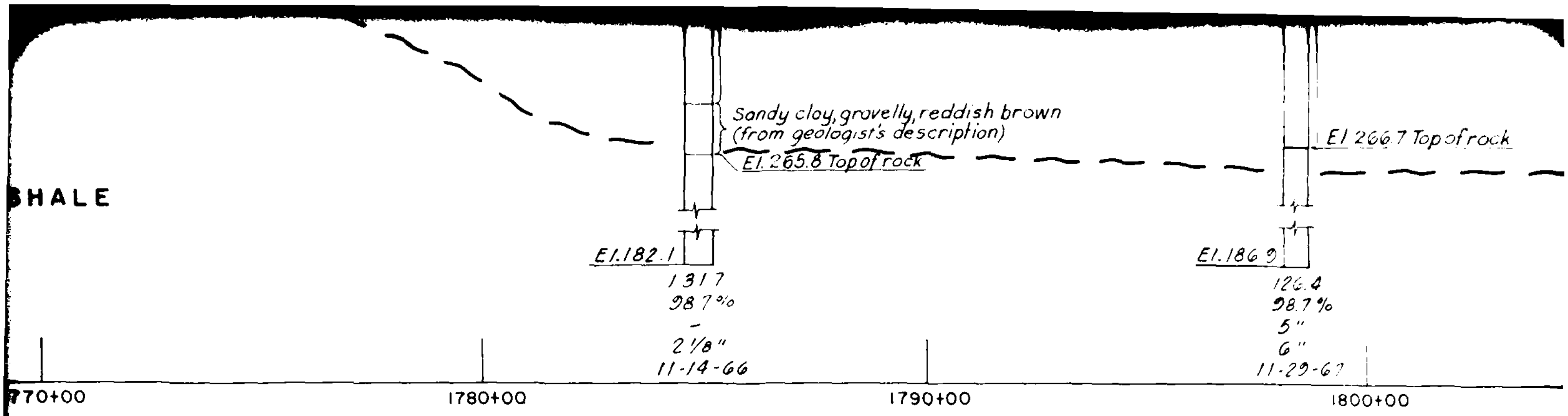


PROFILE ALONG ALIGNMENT A-1 FROM STATION 1815+00 TO 1875+00

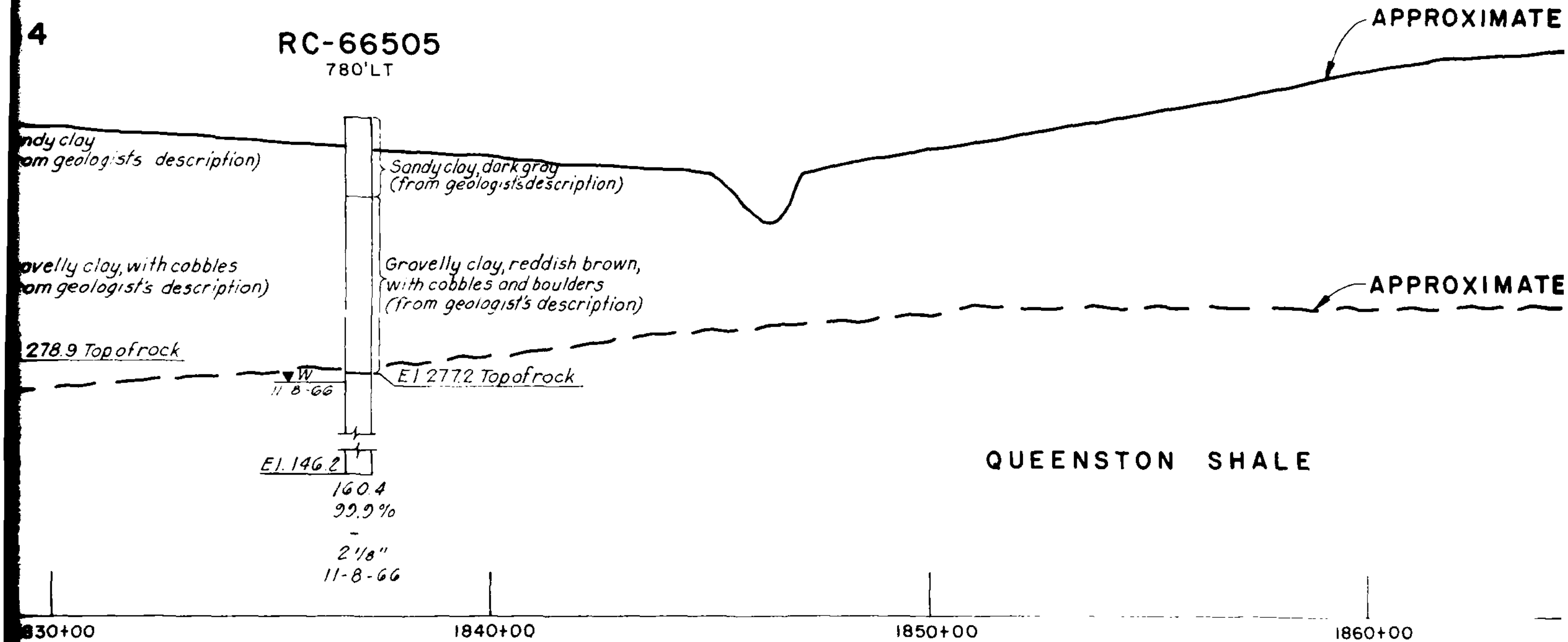
NOTES:

FOR LOCATION OF BORINGS SEE PLATE 8A


AUC-67516
425'LT
ARC-66510
675'LT
G
γd
C
ω
No
2.73
2.75
2.74
1.06
1.04
0.50
1.00
0.71
25.9
18.9
23.4
1
2
3
Sandy clay
Auger
Auger refused
Sandy clay, gravelly with cobbles
El 266.7 Top of rock
El. 186.9
126.4
98.7%
5"
6"
11-29-67
Auger
Sandy clay, gray (from geologist's description)
Fishtail
Gravelly clay, reddish brown (from geologist's description)
El. 292.9 Top of rock
El. 181.9
130.5
98.8%
–
2 1/8"
11-18-66
320
310
300
290
280
270
260
250
1800+00
1810+00
1815+00
+00
APPROXIMATE GROUND SURFACE
APPROXIMATE TOP OF ROCK
STON SHALE
310
300
290
280
270
260
1860+00
1870+00
1875+00
5+00



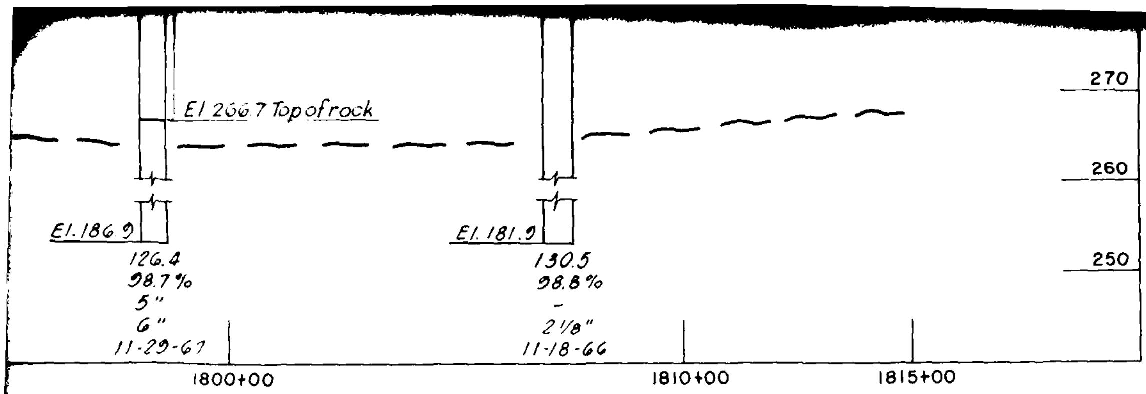
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1755+00 TO 1815+00

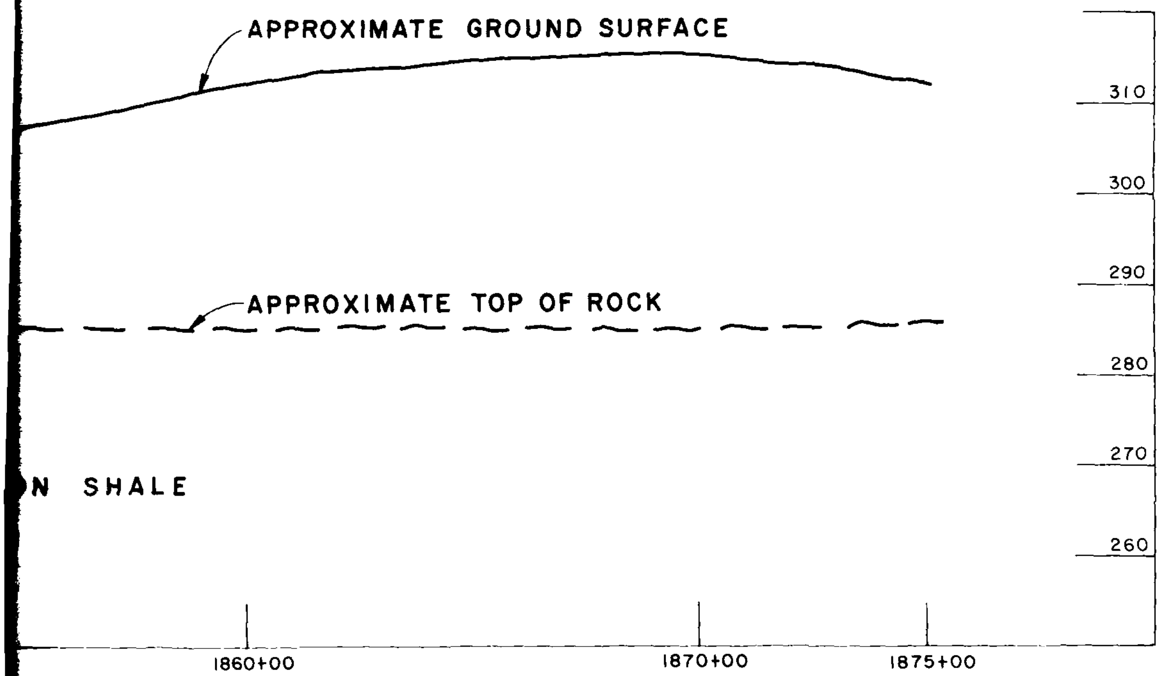


PROFILE ALONG ALIGNMENT A-1 FROM STATION 1815+00 TO 1875+00

NOTES:

FOR LOCATION OF BORINGS, SEE PLATE B4.
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS, SEE PLATE B11.





E B4.
NOTES

LAKE ERIE-LAKE ONTARIO WATERWAY

SOIL PROFILE OF OVERLAND SECTION STATION 1755+00 TO 1875+00 ℄ CANAL

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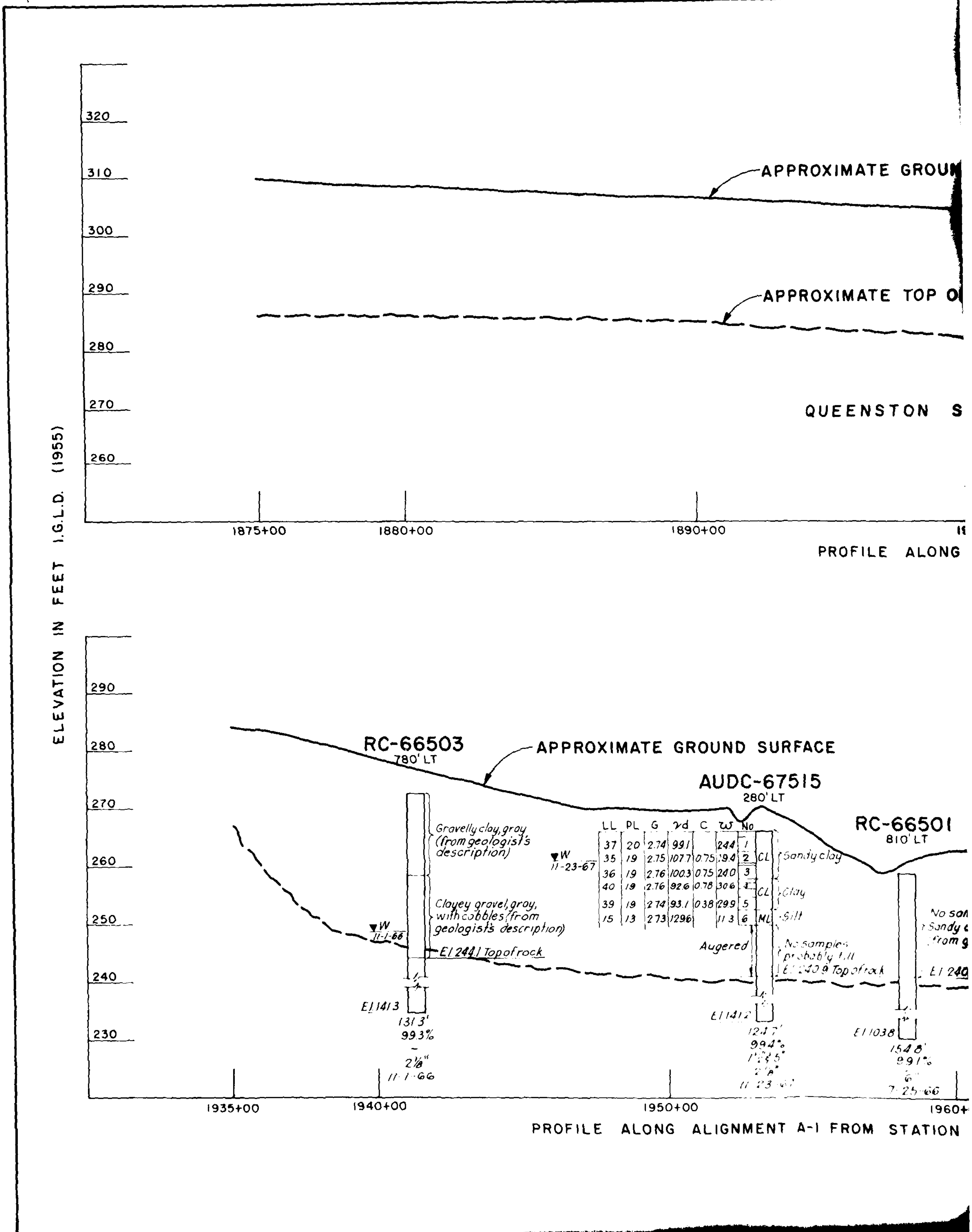
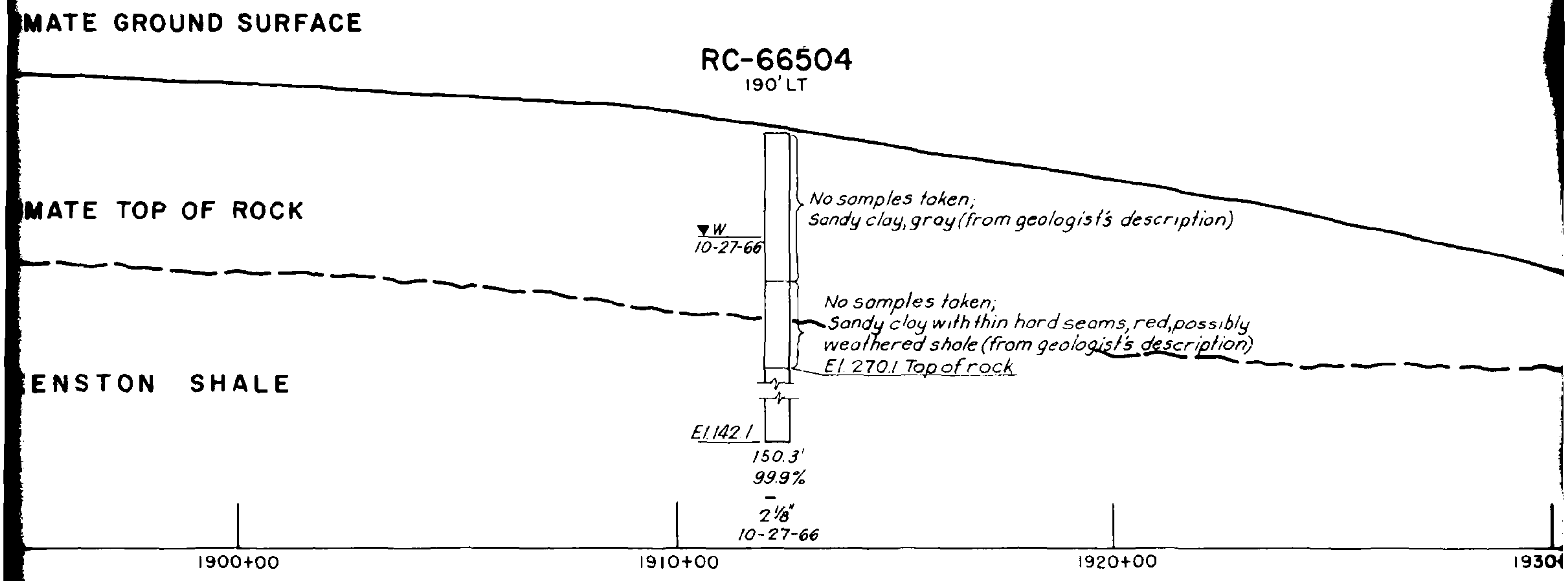
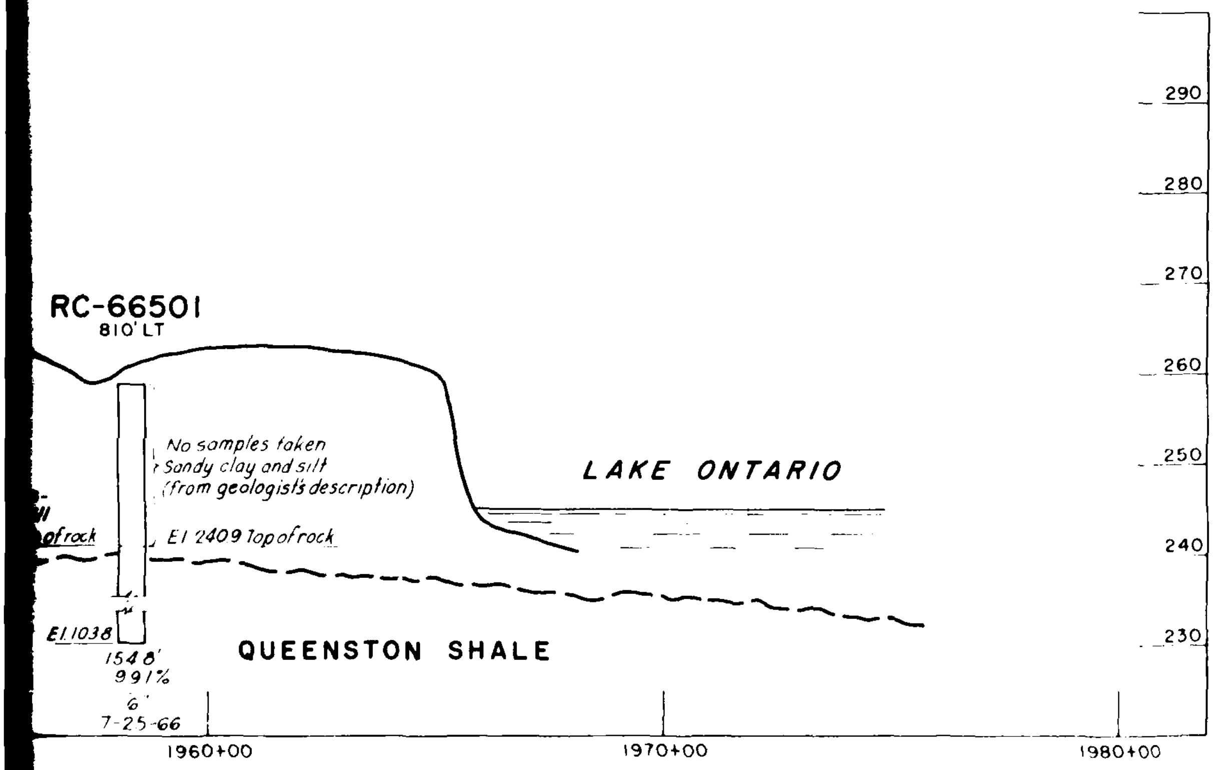
PLATE B17



ELEVATION IN FEET I.G.L.D. (1955)
320
310
300
290
280
270
260
APPROXIMATE GROUN
APPROXIMATE TOP O
QUEENSTON S
1875+00
1880+00
1890+00
PROFILE ALONG
290
280
270
260
250
240
230
RC-66503
780' LT
APPROXIMATE GROUND SURFACE
AUDC-67515
280' LT
RC-66501
810' LT
Gravelly clay, gray (from geologist's description)
Clayey gravel, gray, with cobbles (from geologist's description)
W 11-1-66
El 244.1 Top of rock
El 141.3
131.3'
99.3%
2 1/8"
11-1-66
LL PL G γd C ω No
37 20 2.74 99.1 24.4 1
35 19 2.75 107.7 0.75 19.4 2
36 19 2.76 100.3 0.75 24.0 3
40 19 2.76 92.6 0.78 30.6 4
39 19 2.74 93.1 0.38 29.9 5
15 13 2.73 129.6 11.3 6
W 11-23-67
CL Sandy clay
CL Clay
ML Silt
Augered
No samples probably fill
El 240.9 Top of rock
El 141.2
El 103.8
154.8'
99.1%
El 240
1935+00
1940+00
1950+00
1960+
PROFILE ALONG ALIGNMENT A-1 FROM STATION

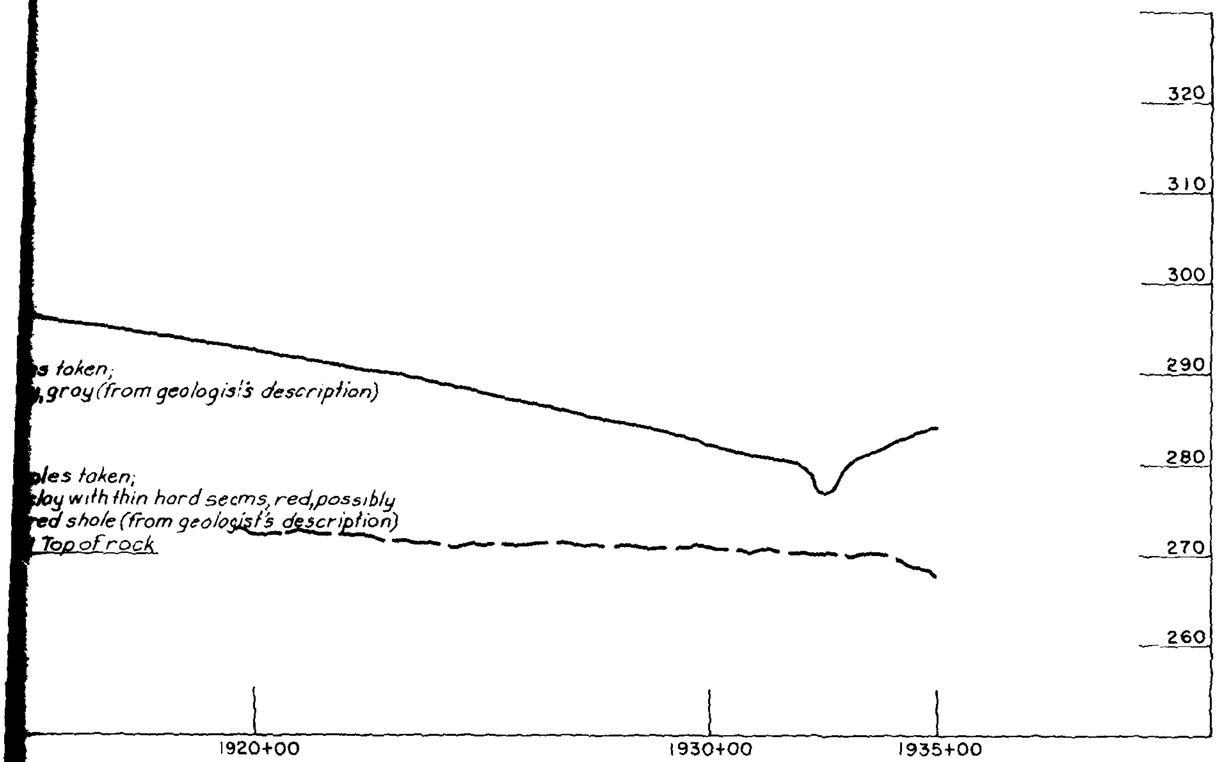


FILE ALONG ALIGNMENT A-1 FROM STATION 1875+00 TO 1935+00



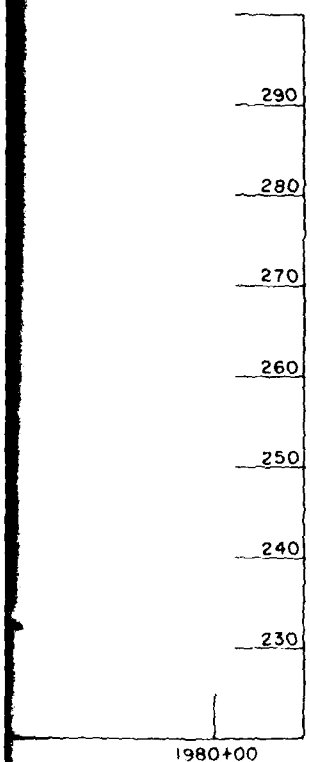
OM STATION 1935+00 TO 1980+00

' 3

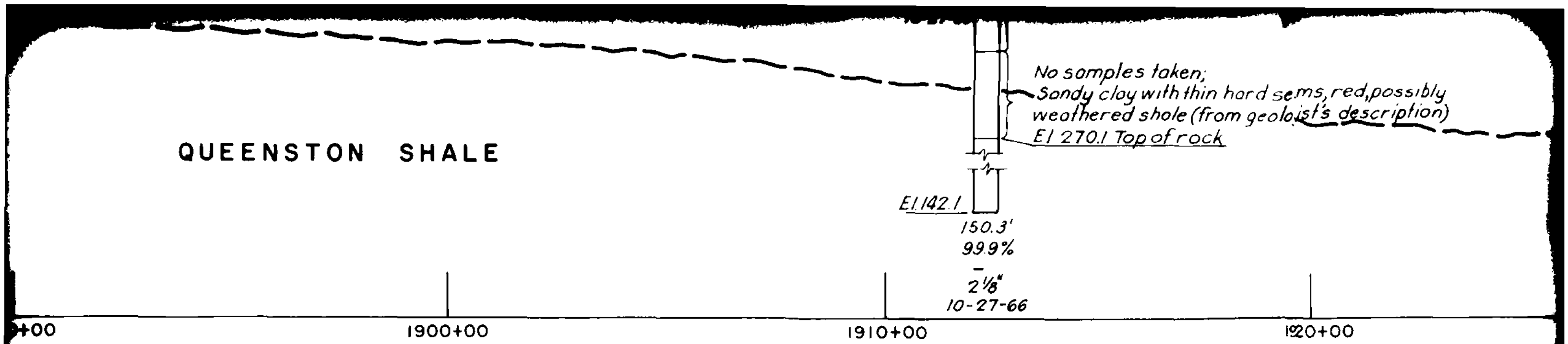


s taken;
,gray (from geologist's description)
ples taken;
clay with thin hard seams, red, possibly
red shale (from geologist's description)
Top of rock
320
310
300
290
280
270
260
1920+00
1930+00
1935+00

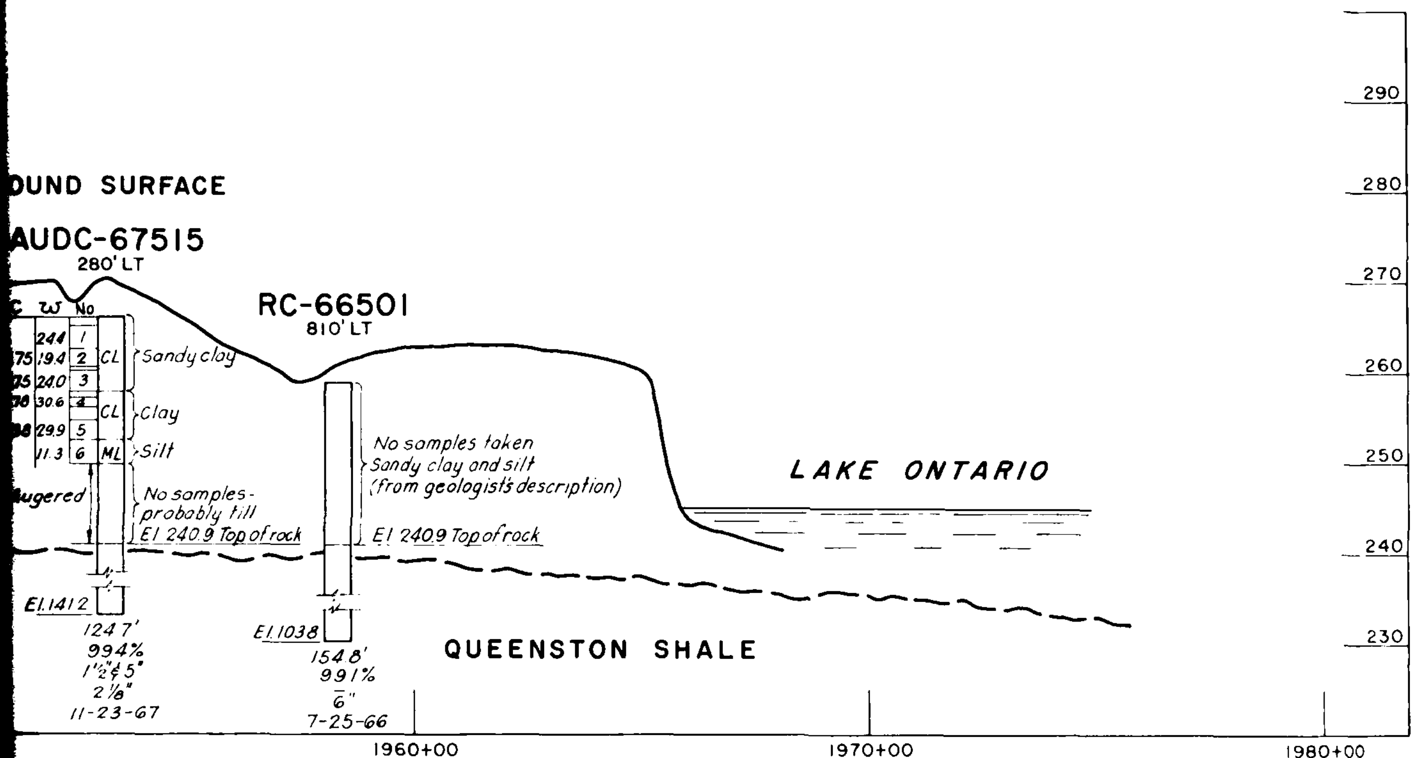
00



290
280
270
260
250
240
230
1980+00



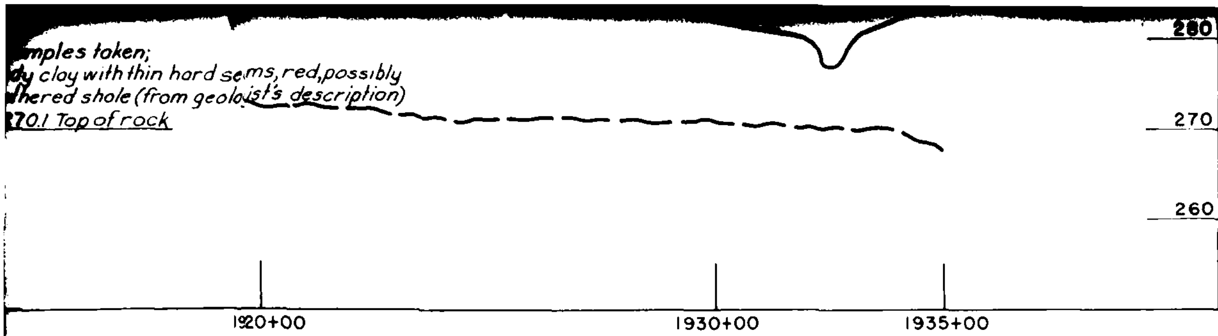
PROFILE ALONG ALIGNMENT A-1 FROM STATION 1875+00 TO 1935+00

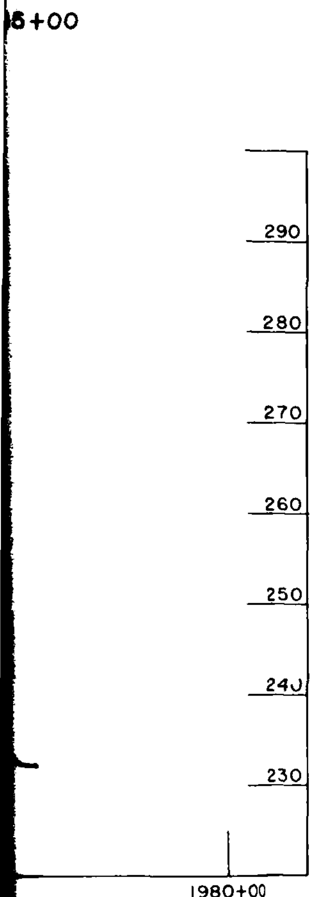


LIGNMENT A-1 FROM STATION 1935+00 TO 1980+00

NOTES:

FOR LOCATION OF BORINGS SEE PLATE B5
FOR LEGEND OF SOIL PROFILES AND NOTES
FOR LOGS OF BORINGS SEE PLATE B11





B5
OTES

LAKE ERIE-LAKE ONTARIO WATERWAY

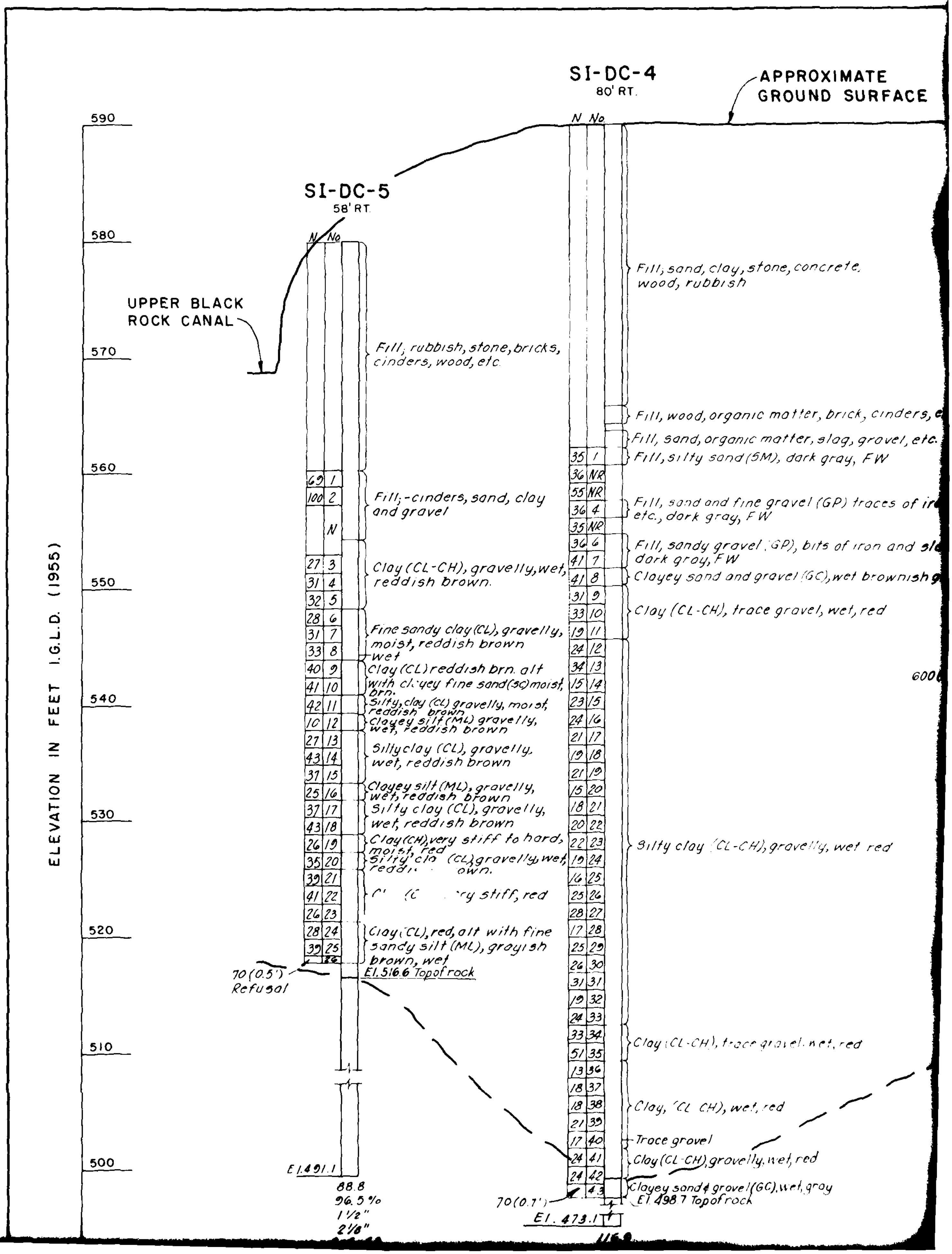
SOIL PROFILE OF OVERLAND SECTION
STATION 1875+00 TO 1980+00 ℄ CANAL

U. S. ARMY ENGINEER DISTRICT, BUFFALO

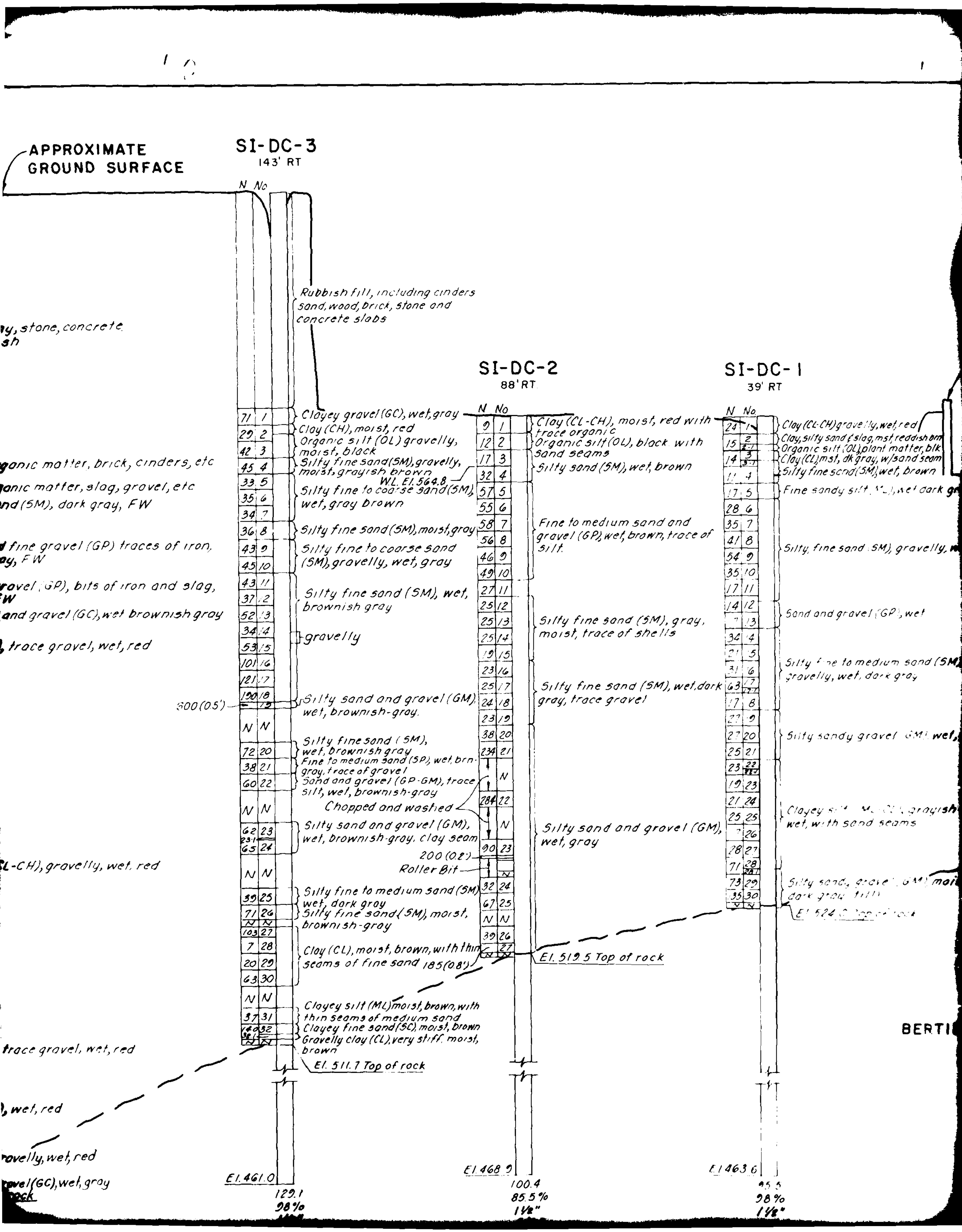
TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

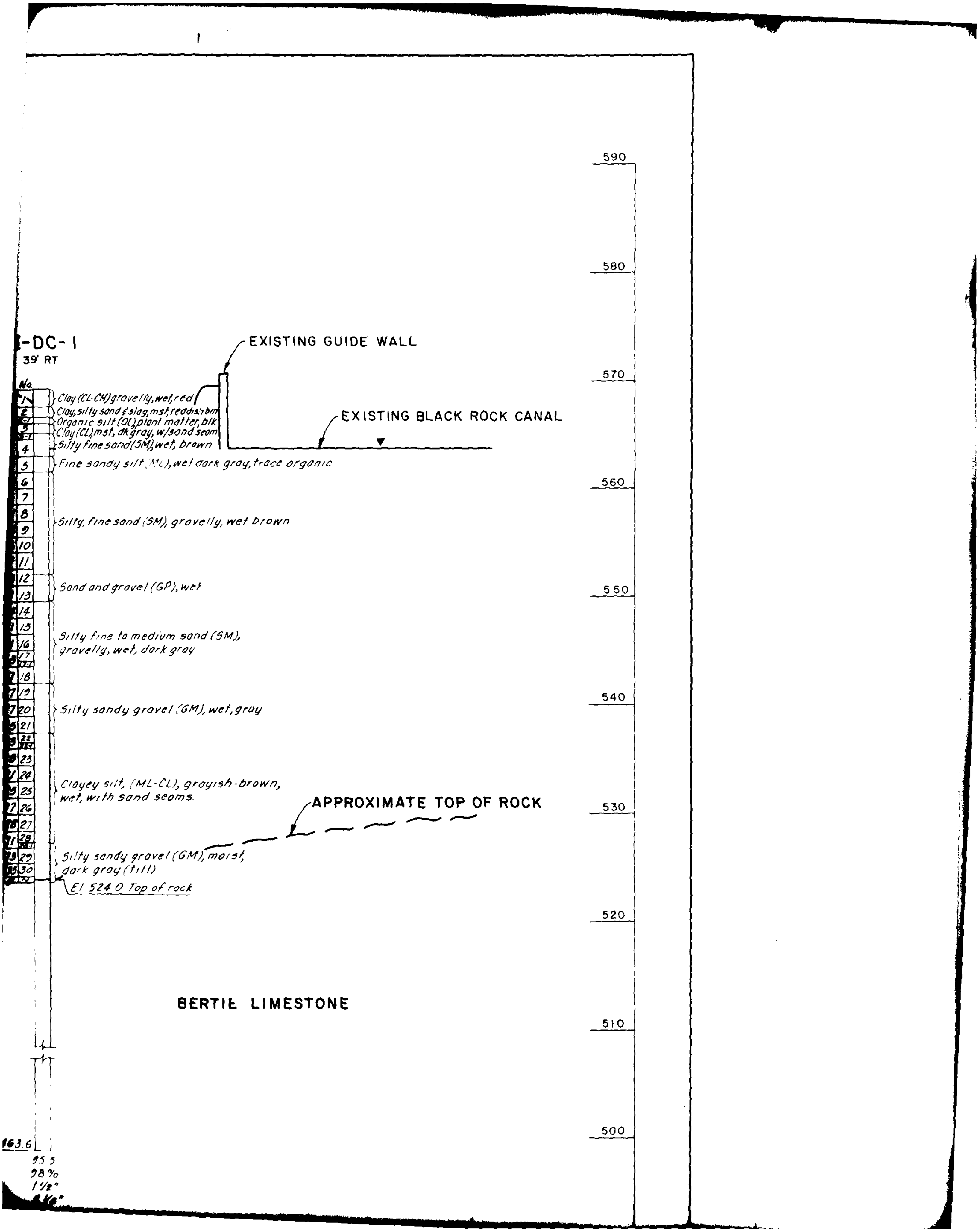
PLATE B1

5

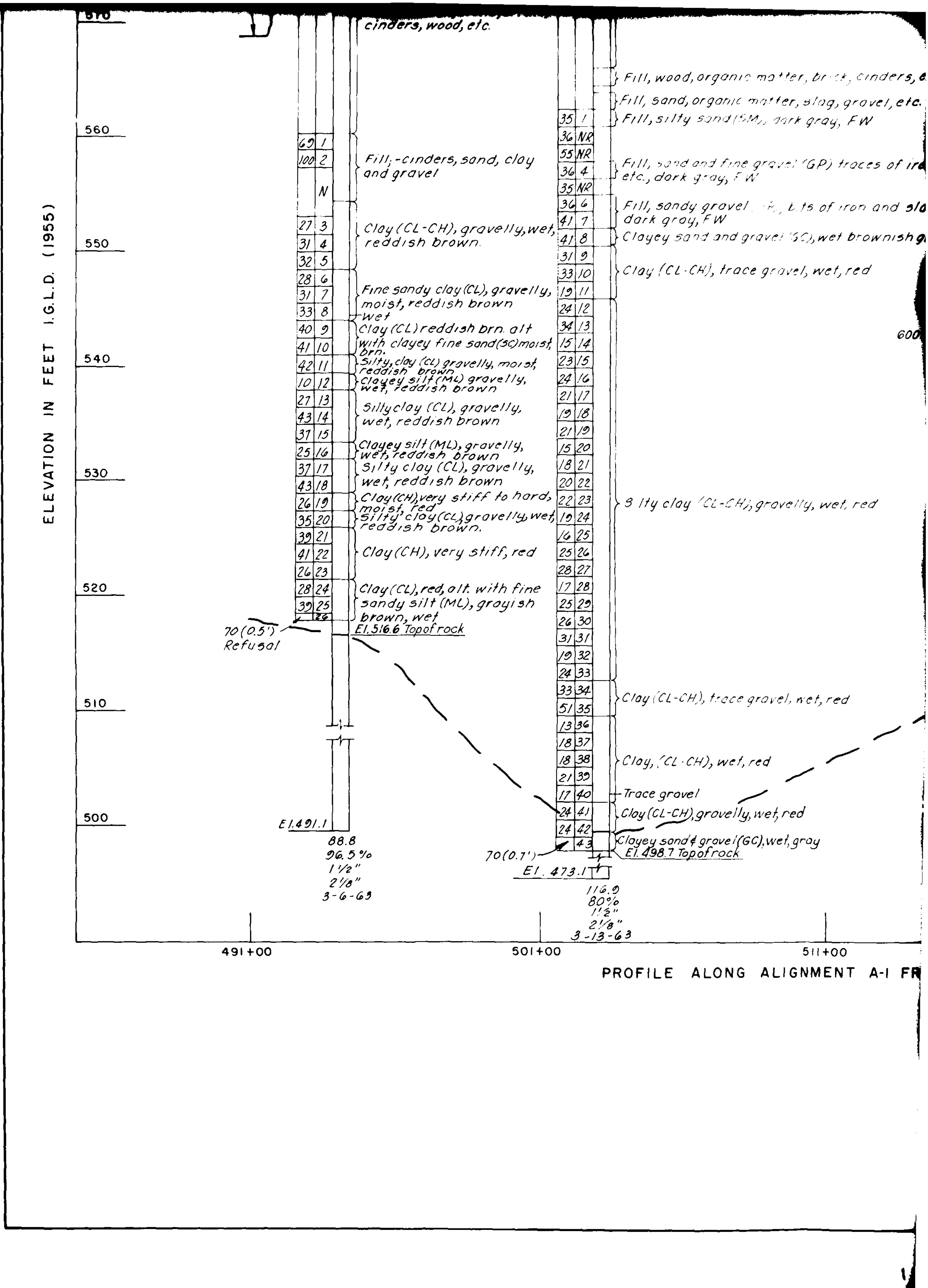


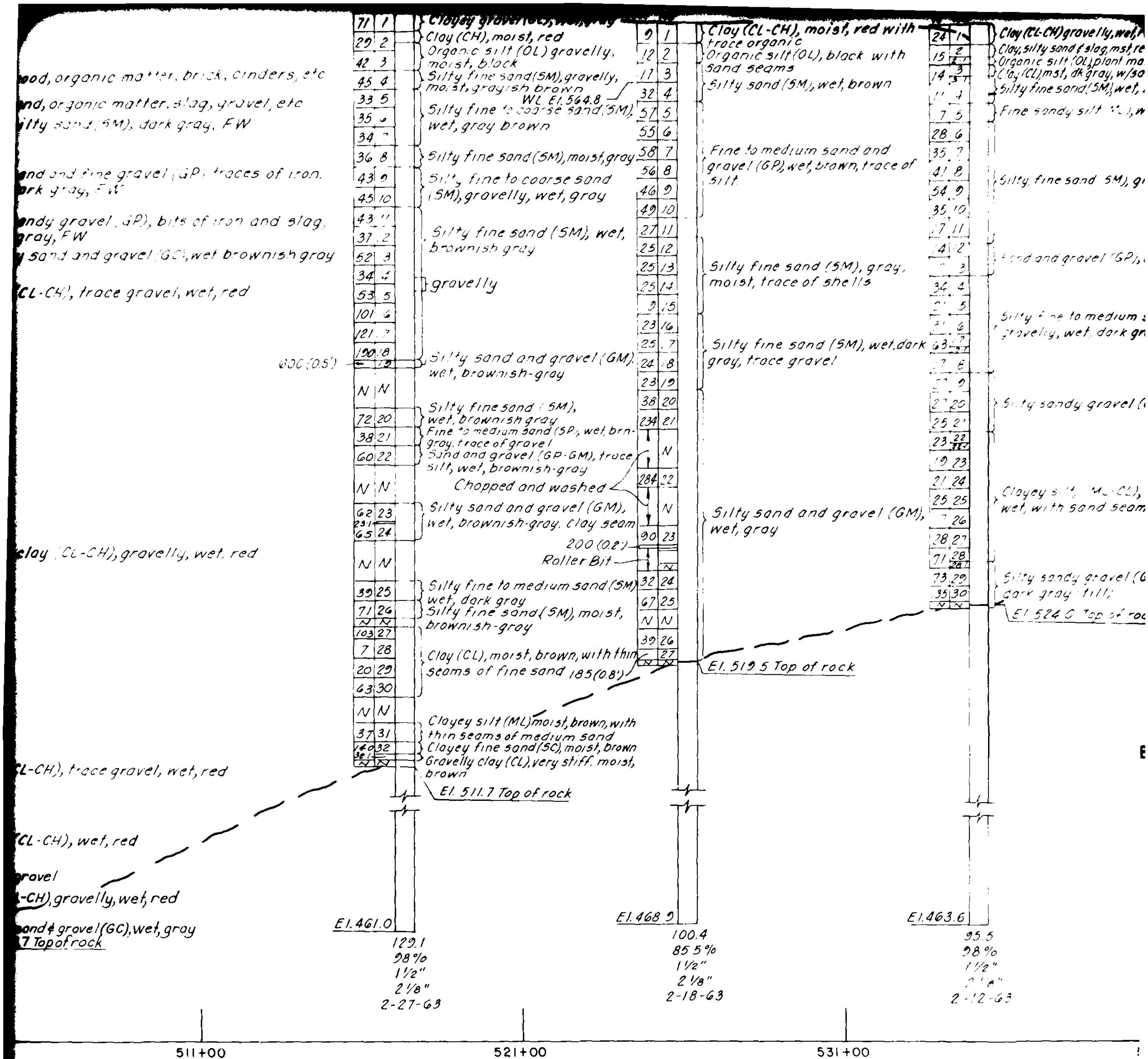
SI-DC-4
80' RT.
APPROXIMATE GROUND SURFACE
SI-DC-5
58' RT.
ELEVATION IN FEET I.G.L.D. (1955)
590
580
570
560
550
540
530
520
510
500
N No
UPPER BLACK ROCK CANAL
Fill, rubbish, stone, bricks, cinders, wood, etc.
Fill, -cinders, sand, clay and gravel
Clay (CL-CH), gravelly, wet, reddish brown.
Fine sandy clay (CL), gravelly, moist, reddish brown
wet
Clay (CL) reddish brn. alt with clayey fine sand (SC) moist, brn.
Silty clay (CL) gravelly, moist, reddish brown
Clayey silt (ML) gravelly, wet, reddish brown
Silty clay (CL), gravelly, wet, reddish brown
Clayey silt (ML), gravelly, wet, reddish brown
Silty clay (CL), gravelly, wet, reddish brown
Clay (CH), very stiff to hard, moist, red
Clay (CL), red, alt with fine sandy silt (ML), grayish brown, wet
70 (0.5') Refusal
El. 516.6 Top of rock
El. 491.1
88.8
96.5 %
1 1/2"
2 1/8"
Fill, sand, clay, stone, concrete, wood, rubbish
Fill, wood, organic matter, brick, cinders, e
Fill, sand, organic matter, slag, gravel, etc.
Fill, silty sand (SM), dark gray, FW
Fill, sand and fine gravel (GP) traces of ir etc., dark gray, FW
Fill, sandy gravel (GP), bits of iron and sl dark gray, FW
Clayey sand and gravel (GC), wet brownish g
Clay (CL-CH), trace gravel, wet, red
600
Silty clay (CL-CH), gravelly, wet red
Clay (CL-CH), trace gravel, wet, red
Clay, (CL CH), wet, red
Trace gravel
Clay (CL-CH) gravelly, wet, red
Clayey sand & gravel (GC), wet, gray
El. 498.7 Top of rock
70 (0.1')
El. 473.1


APPROXIMATE GROUND SURFACE
SI-DC-3
143' RT
N No
Rubbish fill, including cinders sand, wood, brick, stone and concrete slabs
Clayey gravel (GC), wet, gray
Clay (CH), moist, red
Organic silt (OL) gravelly, moist, black
Silty fine sand (SM), gravelly, moist, grayish brown
Silty fine to coarse sand (SM), wet, gray brown
Silty fine sand (SM), moist, gray
Silty fine to coarse sand (SM), gravelly, wet, gray
Silty fine sand (SM), wet, brownish gray
gravelly
Silty sand and gravel (GM), wet, brownish-gray.
300 (0.5')
Silty fine sand (SM), wet, brownish gray
Fine to medium sand (SP), wet, brn-gray, trace of gravel
Sand and gravel (GP-GM), trace silt, wet, brownish-gray
Chopped and washed
Silty sand and gravel (GM), wet, brownish-gray, clay seam
200 (0.2')
Roller Bit
Silty fine to medium sand (SM) wet, dark gray
Silty fine sand (SM), moist, brownish-gray
Clay (CL), moist, brown, with thin seams of fine sand
185 (0.8')
Clayey silt (ML) moist, brown, with thin seams of medium sand
Clayey fine sand (SC), moist, brown
Gravelly clay (CL), very stiff, moist, brown
El. 511.7 Top of rock
El. 461.0
129.1
98%
SI-DC-2
88' RT
N No
Clay (CL-CH), moist, red with trace organic
Organic silt (OL), black with sand seams
Silty sand (SM), wet, brown
W.L. El. 564.8
Fine to medium sand and gravel (GP), wet, brown, trace of silt.
Silty fine sand (SM), gray, moist, trace of shells
Silty fine sand (SM), wet, dark gray, trace gravel
Silty sand and gravel (GM), wet, gray
El. 519.5 Top of rock
El. 468.9
100.4
85.5%
1½"
SI-DC-1
39' RT
N No
Clay (CL-CH) gravelly, wet, red
Clay, silty sand & slag, mst, reddish brn
Organic silt (OL) plant matter, blk
Clay (CL) mst, dk gray, w/sand seam
Silty fine sand (SM), wet, brown
Fine sandy silt
Silty fine sand (SM), gravelly
Sand and gravel (GP), wet
Silty fine to medium sand (SM) gravelly, wet, dark gray
Silty sandy gravel
wet, with sand seams
El. 463.6
98%
1½"
BERTI
stone, concrete
organic matter, brick, cinders, etc
organic matter, slag, gravel, etc
sand (SM), dark gray, FW
fine gravel (GP) traces of iron, FW
gravel (GP), bits of iron and slag, FW
sand and gravel (GC), wet brownish gray
trace gravel, wet, red
(CL-CH), gravelly, wet, red
trace gravel, wet, red
wet, red
gravelly, wet, red
gravel (GC), wet, gray
rock



-DC-1
39' RT
No.
Clay (CL-CH) gravelly, wet, red
Clay, silty sand & slag, mst, reddish brn
Organic silt (OL) plant matter, blk
Clay (CL) mst, dk gray, w/sand seam
Silty fine sand (SM), wet, brown
Fine sandy silt (ML), wet dark gray, trace organic
Silty, fine sand (SM), gravelly, wet brown
Sand and gravel (GP), wet
Silty fine to medium sand (SM), gravelly, wet, dark gray.
Silty sandy gravel (GM), wet, gray
Clayey silt, (ML-CL), grayish-brown, wet, with sand seams.
Silty sandy gravel (GM), moist, dark gray (till)
El 524.0 Top of rock
EXISTING GUIDE WALL
EXISTING BLACK ROCK CANAL
APPROXIMATE TOP OF ROCK
BERTIE LIMESTONE
590
580
570
560
550
540
530
520
510
500
163.6
95.5
98%
1½"


ELEVATION IN FEET I.G.L.D. (1955)
560
550
540
530
520
510
500
cinders, wood, etc.
Fill; -cinders, sand, clay and gravel
Clay (CL-CH), gravelly, wet, reddish brown.
Fine sandy clay (CL), gravelly, moist, reddish brown
wet
Clay (CL) reddish brn. alt with clayey fine sand (SC) moist, brn.
Silty, clay (CL) gravelly, moist, reddish brown
Clayey silt (ML) gravelly, wet, reddish brown
Siltyclay (CL), gravelly, wet, reddish brown
Clayey silt (ML), gravelly, wet, reddish brown
Silty clay (CL), gravelly, wet, reddish brown
Clay (CH) very stiff to hard, moist, red
Silty clay (CL), gravelly, wet, reddish brown.
Clay (CH), very stiff, red
Clay (CL), red, alt. with fine sandy silt (ML), grayish brown, wet
El. 516.6 Top of rock
70 (0.5') Refusal
El. 491.1
88.8
96.5%
1 1/2"
2 1/8"
3-6-63
Fill, wood, organic matter, brick, cinders, etc.
Fill, sand, organic matter, slag, gravel, etc.
Fill, silty sand (SM), dark gray, FW
Fill, sand and fine gravel (GP) traces of iron etc., dark gray, FW
Fill, sandy gravel, bits of iron and slag dark gray, FW
Clayey sand and gravel (SC), wet brownish gray
Clay (CL-CH), trace gravel, wet, red
600
Silty clay (CL-CH), gravelly, wet, red
Clay (CL-CH), trace gravel, wet, red
Clay, (CL-CH), wet, red
Trace gravel
Clay (CL-CH), gravelly, wet, red
Clayey sand & gravel (GC), wet, gray
El. 498.7 Top of rock
70 (0.7')
El. 473.1
116.9
80%
1 1/2"
2 1/8"
3-13-63
491+00
501+00
511+00
PROFILE ALONG ALIGNMENT A-I FR



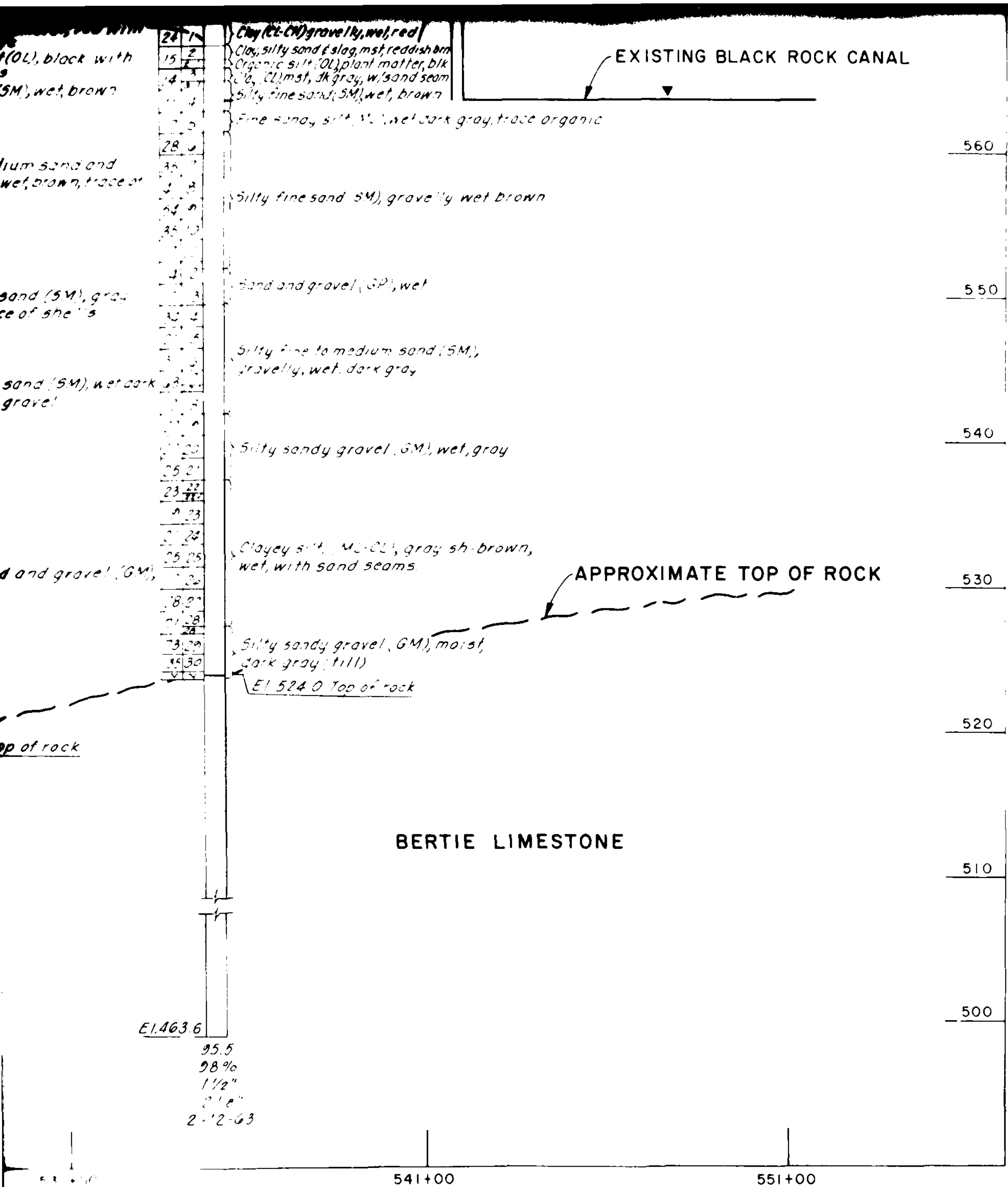
E ALONG ALIGNMENT A-1 FROM STATION 491+00 TO 551+00

NOTES:

FOR LOCATION OF BORINGS, SEE PLATE B6.

FOR DETAILED DESCRIPTION OF ROCK CORE FOR LOCK 5-5, SEE PLATE B24.

FOR LEGEND OF SOIL PROFILES AND NOTES FOR LOGS OF BORINGS, SEE PLATE B11



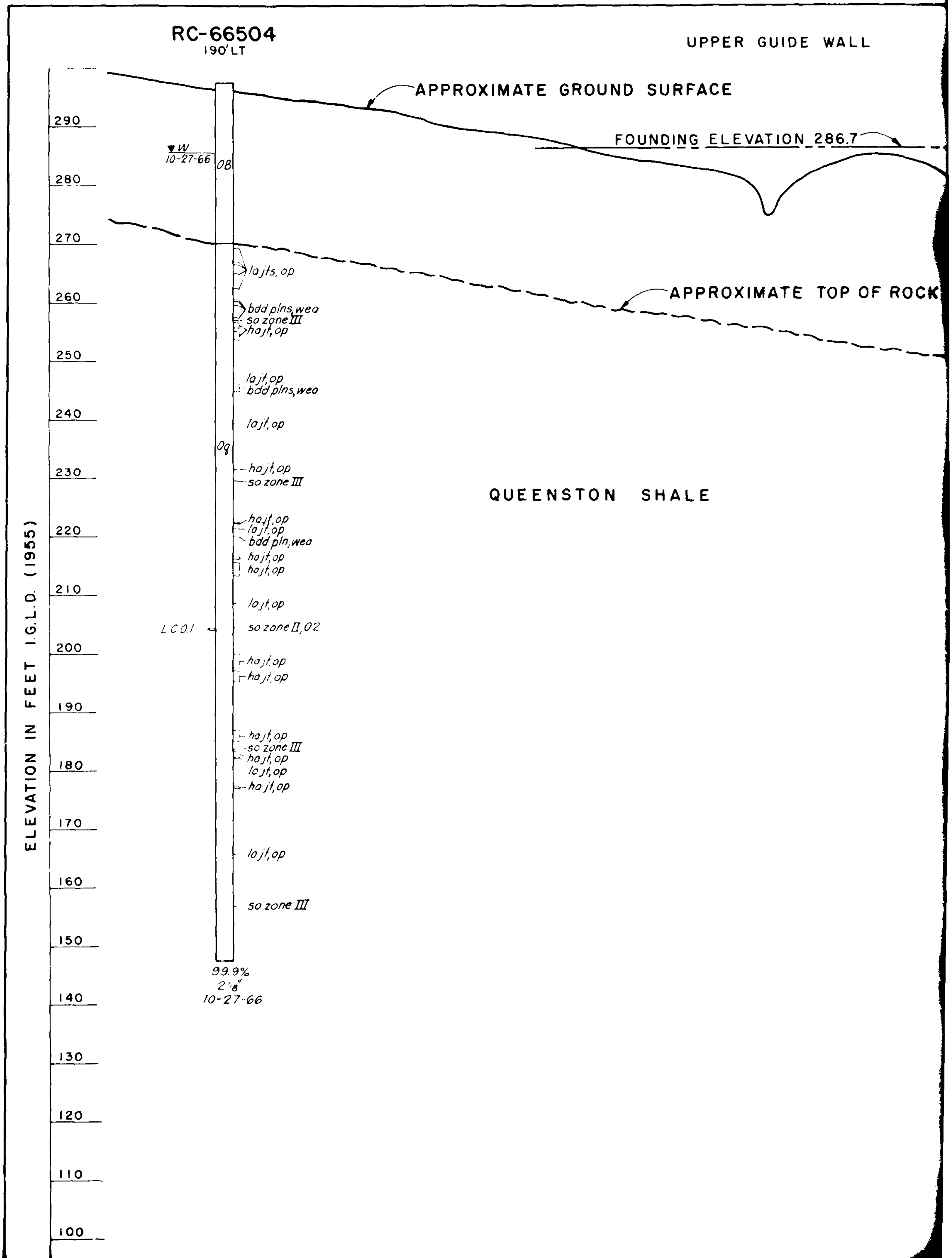
LAKE ERIE-LAKE ONTARIO WATERWAY

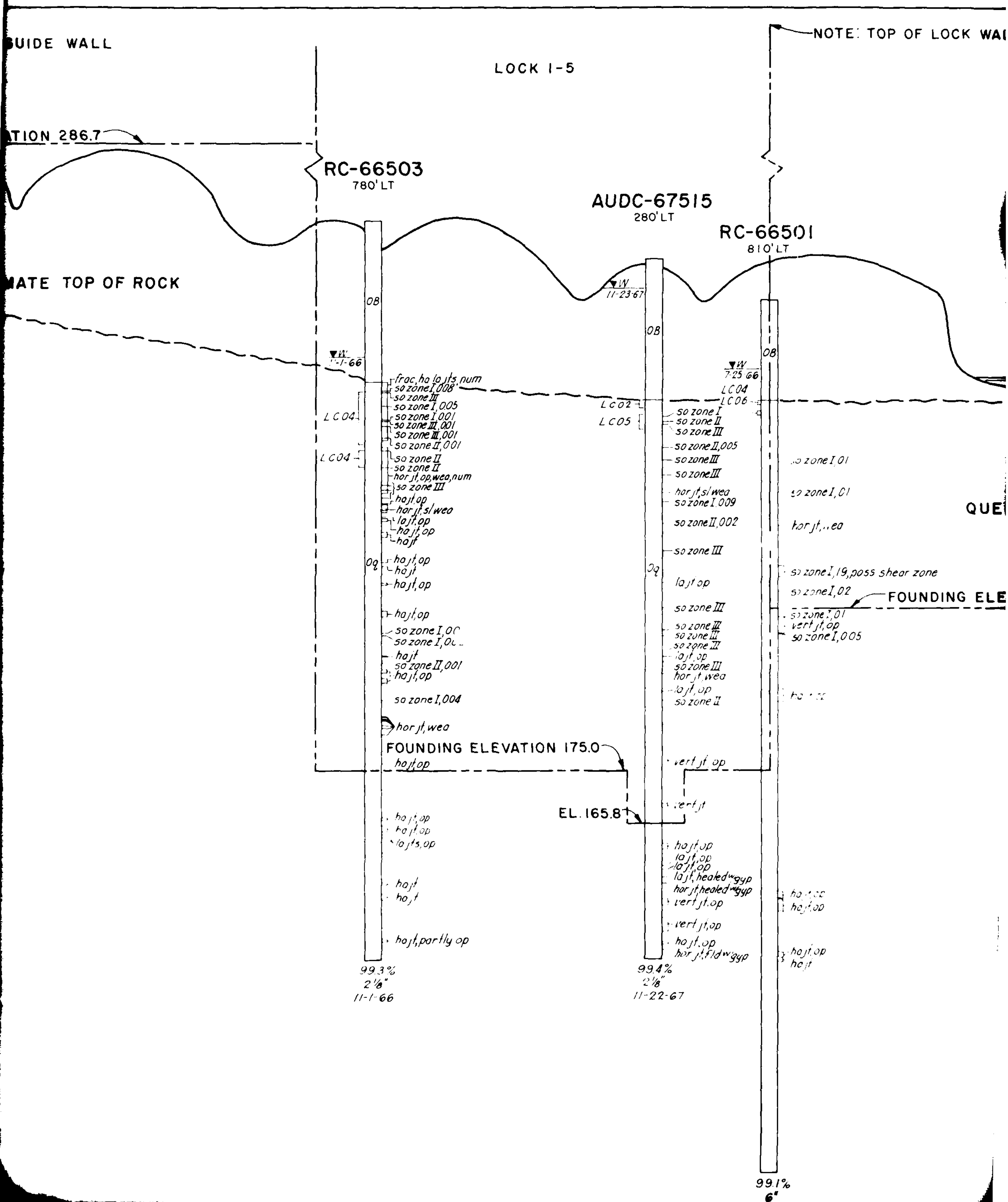
SOIL PROFILE
LOCK 5-5

ARMY ENGINEER DISTRICT, BUFFALO

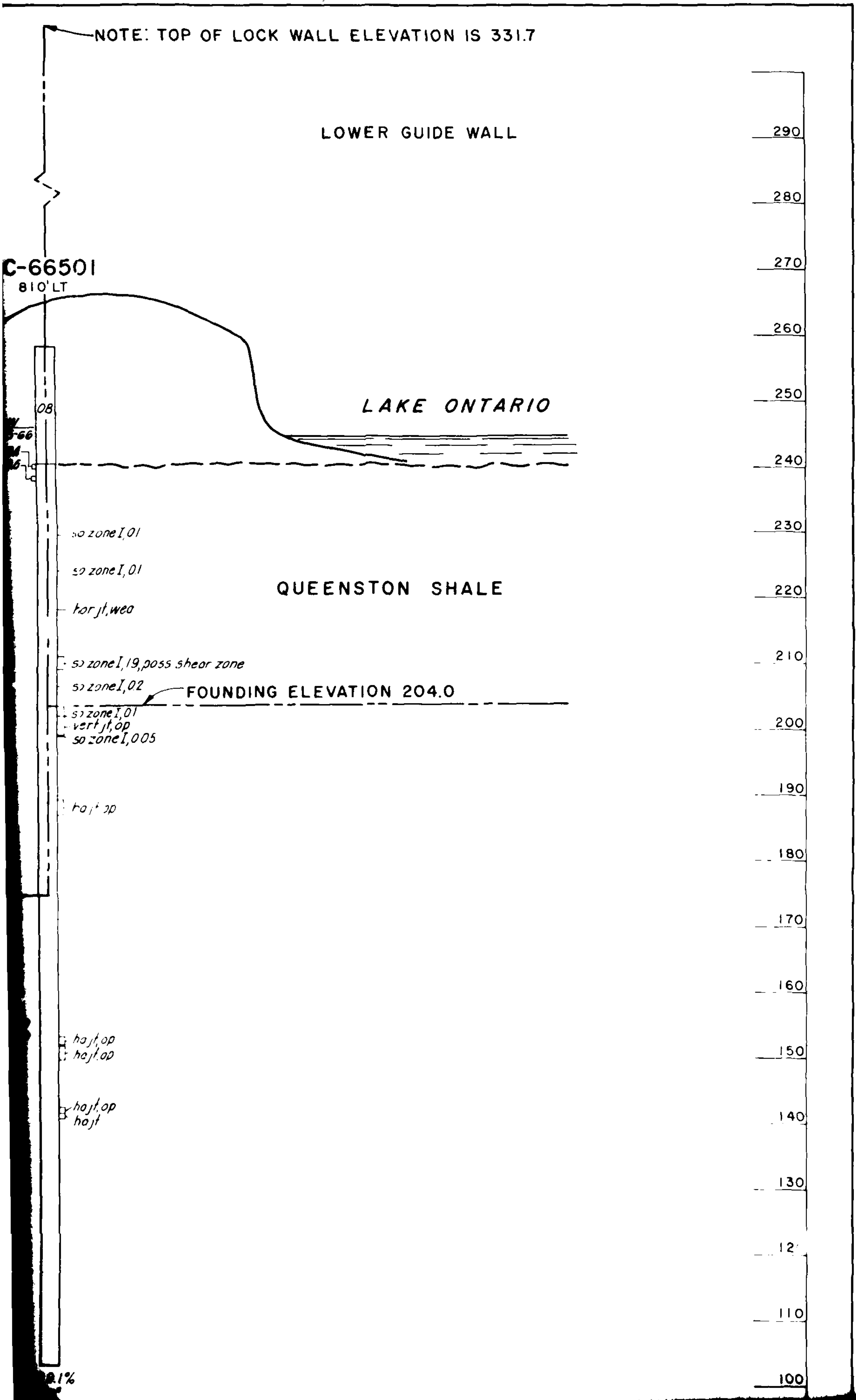
REVIEW OF REPORTS

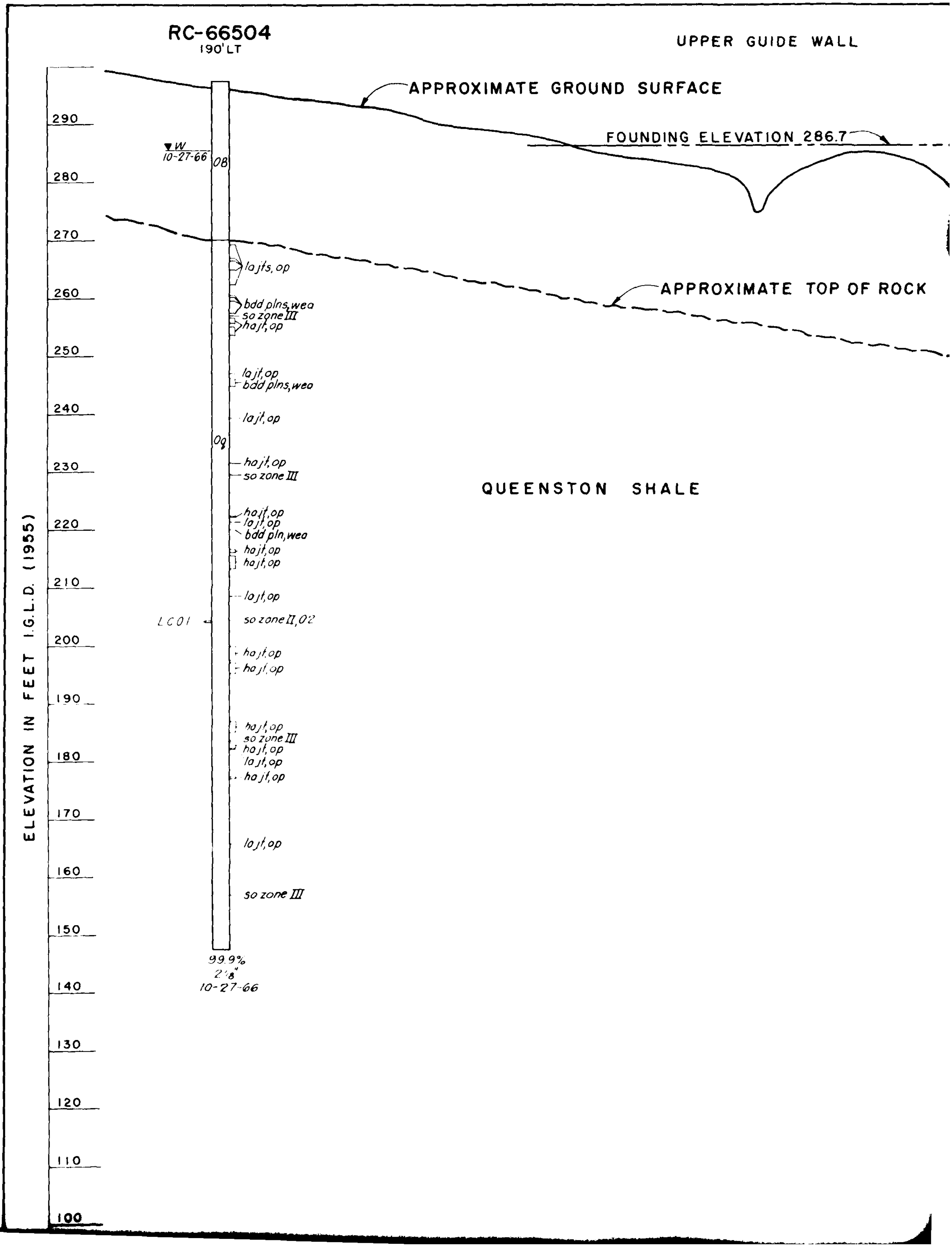
TOBER 1973


RC-66504
190'LT
UPPER GUIDE WALL
APPROXIMATE GROUND SURFACE
FOUNDING ELEVATION 286.7
APPROXIMATE TOP OF ROCK
QUEENSTON SHALE
ELEVATION IN FEET I.G.L.D. (1955)
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
W
10-27-66
OB
Oq
LC01
lo jts, op
bdd plns, weo
so zone III
ho jt, op
lo jt, op
bdd plns, weo
lo jt, op
ho jt, op
so zone III
ho jt, op
lo jt, op
bdd pln, weo
ho jt, op
ho jt, op
lo jt, op
so zone II, 02
ho jt, op
ho jt, op
ho jt, op
so zone III
ho jt, op
lo jt, op
ho jt, op
lo jt, op
so zone III
99.9%
2'8"
10-27-66

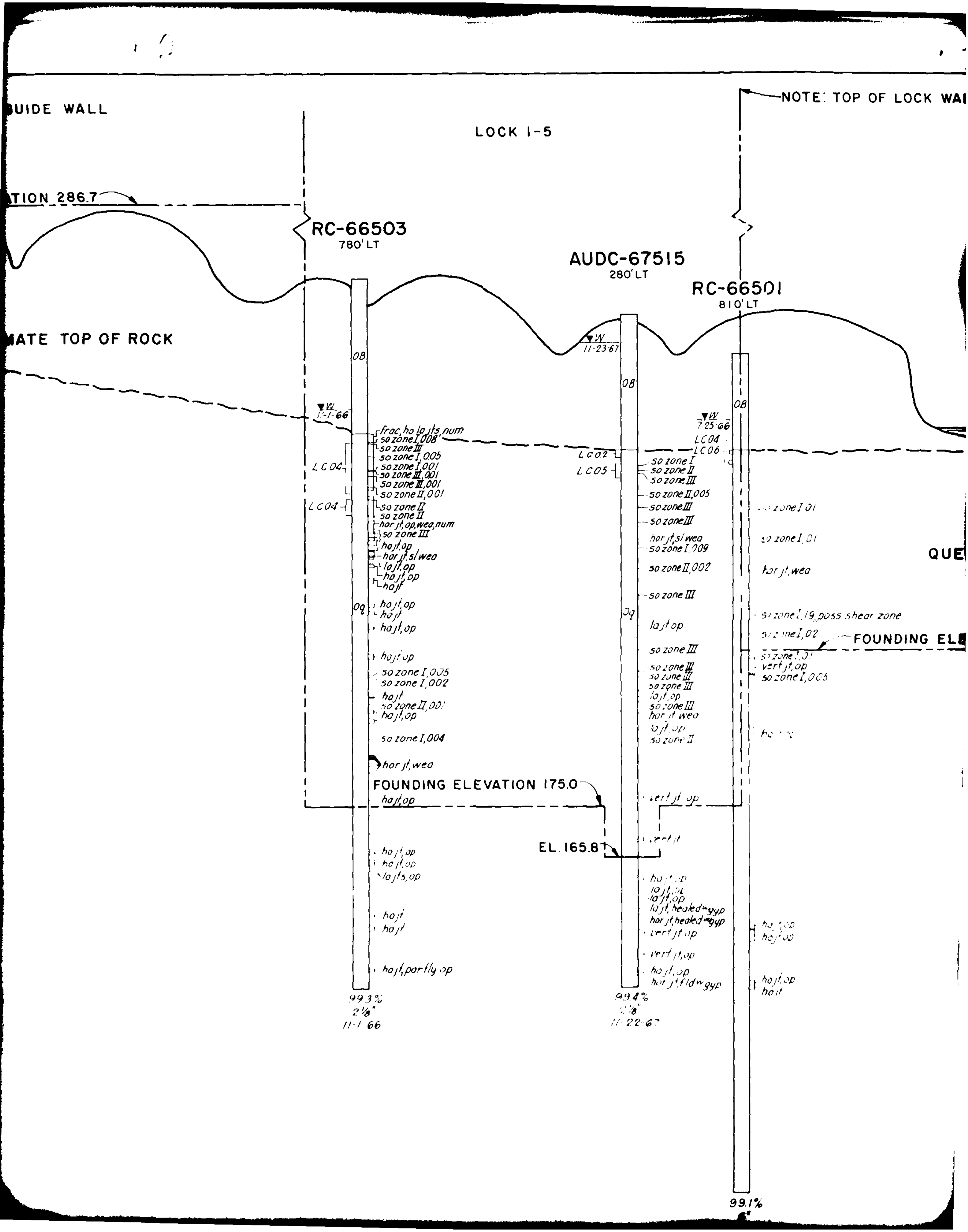


UIDE WALL
LOCK I-5
NOTE: TOP OF LOCK WAI
TION 286.7
RC-66503
780' LT
AUDC-67515
280' LT
RC-66501
810' LT
IATE TOP OF ROCK
OB
Oq
LC04
LC02
LC05
LC06
frac, ho lo jts, num
so zone I, 008
so zone III
so zone I, 005
so zone I, 001
so zone III, 001
so zone II, 001
so zone II
hor jt, op, wea, num
ho jt, op
hor jt, sl wea
lo jt, op
ho jt
so zone I, 004
hor jt, wea
FOUNDING ELEVATION 175.0
ho jt op
ho jt, partly op
lo jts, op
so zone I
so zone II, 005
hor jt, sl wea
so zone I, 009
so zone II, 002
lo jt op
hor jt, wea
vert jt, op
vert jt
EL. 165.8
lo jt, healed w gyp
hor jt, healed w gyp
hor jt, fld w gyp
so zone I, 01
so zone I, 19, poss shear zone
so zone I, 02
FOUNDING ELE
so zone I, 005
QUE
99.3%
2 1/8"
11-1-66
99.4%
2 1/8"
11-22-67
99.1%
6"

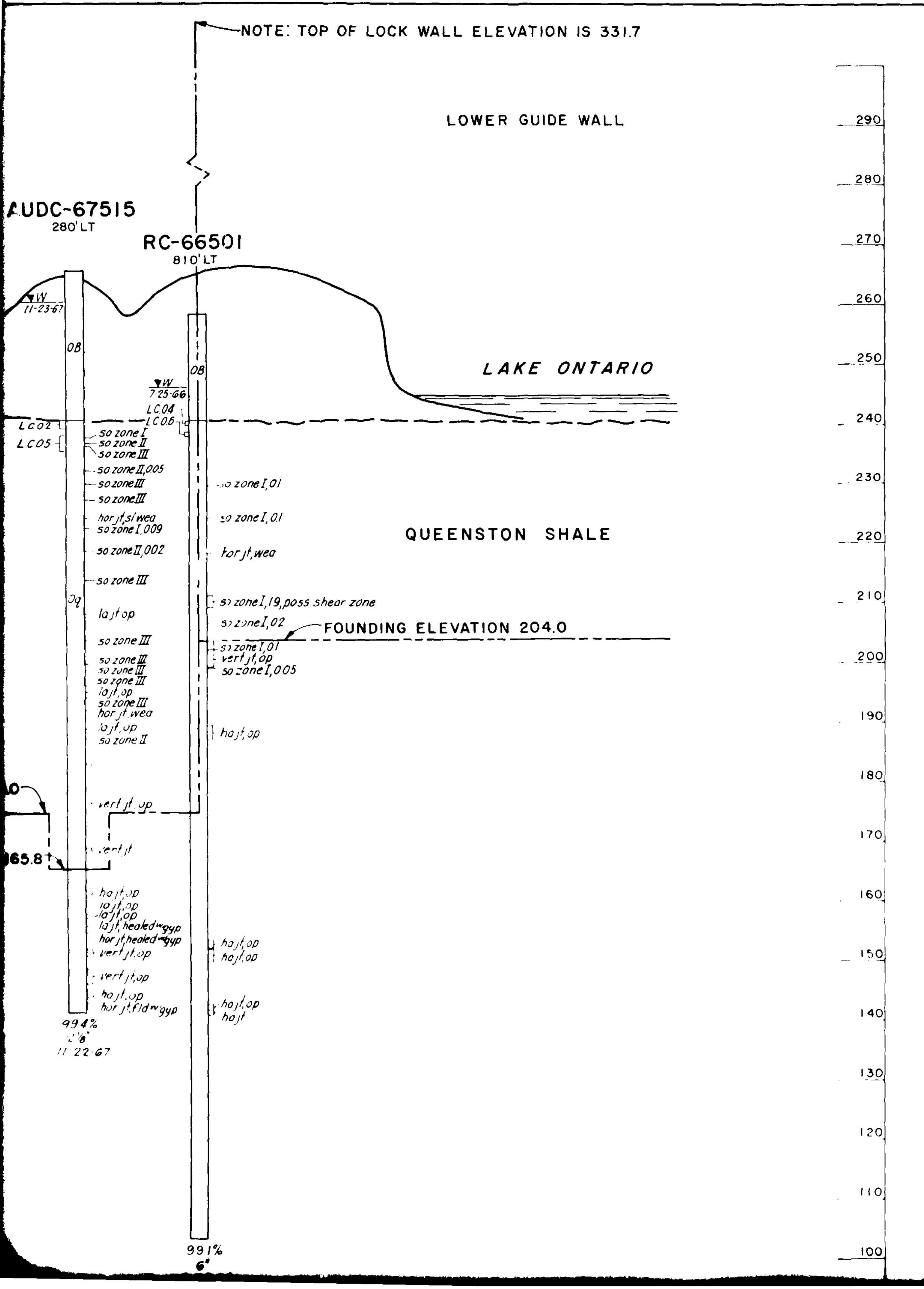

NOTE: TOP OF LOCK WALL ELEVATION IS 331.7
LOWER GUIDE WALL
C-66501
810'LT
LAKE ONTARIO
QUEENSTON SHALE
FOUNDING ELEVATION 204.0
so zone I, 01
so zone I, 01
hor jt, wea
so zone I, 19, poss shear zone
so zone I, 02
so zone I, 01
vert jt, op
so zone I, 005
ho jt, op
ho jt, op
ho jt, op
ho jt
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
110
100



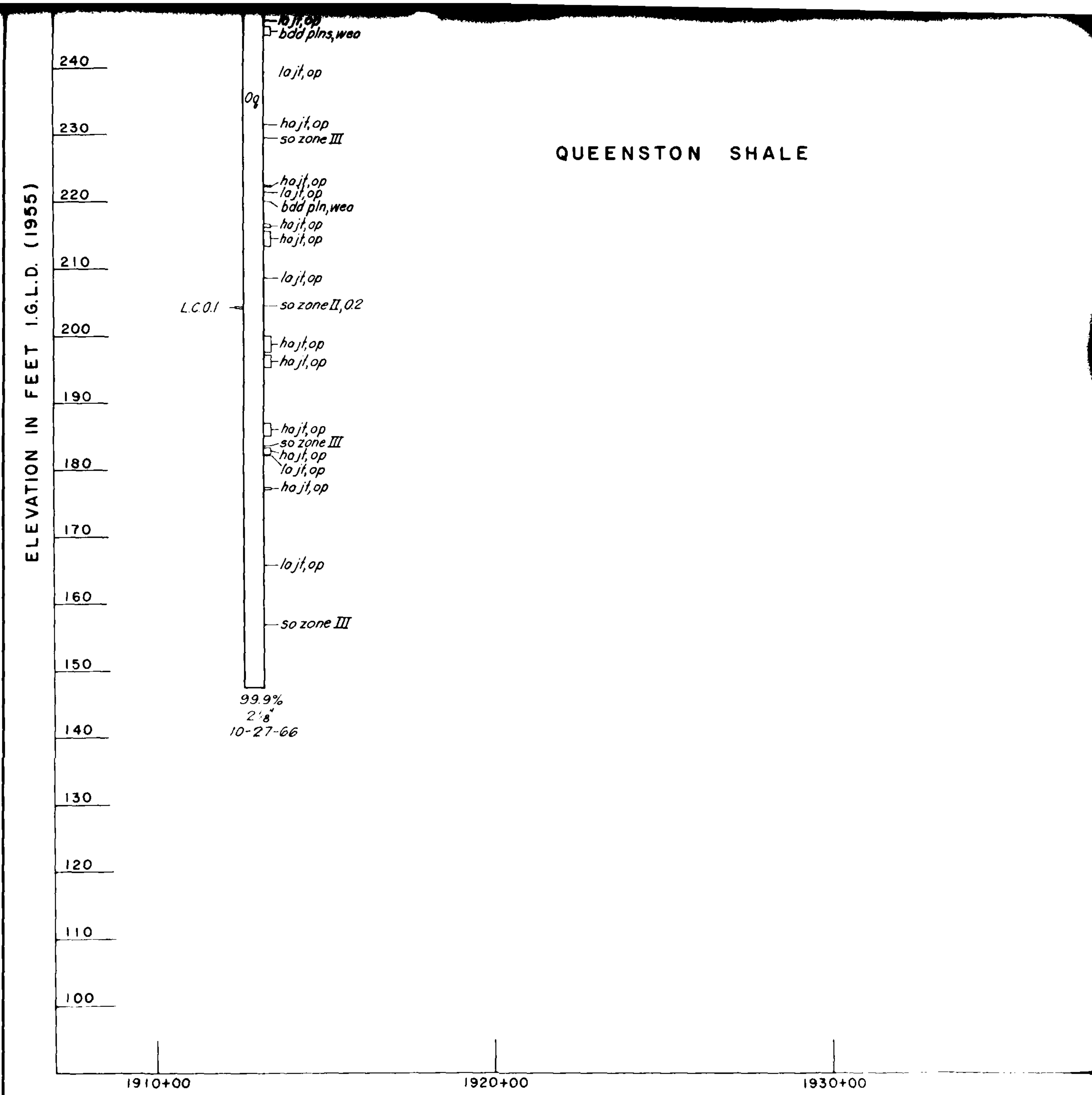
RC-66504
190' LT
UPPER GUIDE WALL
APPROXIMATE GROUND SURFACE
FOUNDING ELEVATION 286.7
APPROXIMATE TOP OF ROCK
QUEENSTON SHALE
ELEVATION IN FEET I.G.L.D. (1955)
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
W
10-27-66
OB
Oq
la jts, op
bdd plns, wea
so zone III
ha jt, op
la jt, op
bdd plns, wea
la jt, op
ha jt, op
so zone III
ha jt, op
la jt, op
bdd pln, wea
ha jt, op
ha jt, op
la jt, op
LC01
so zone II, 02
ha jt, op
ha jt, op
ha jt, op
so zone III
ha jt, op
la jt, op
ha jt, op
la jt, op
so zone III
99.9%
2 1/8"
10-27-66



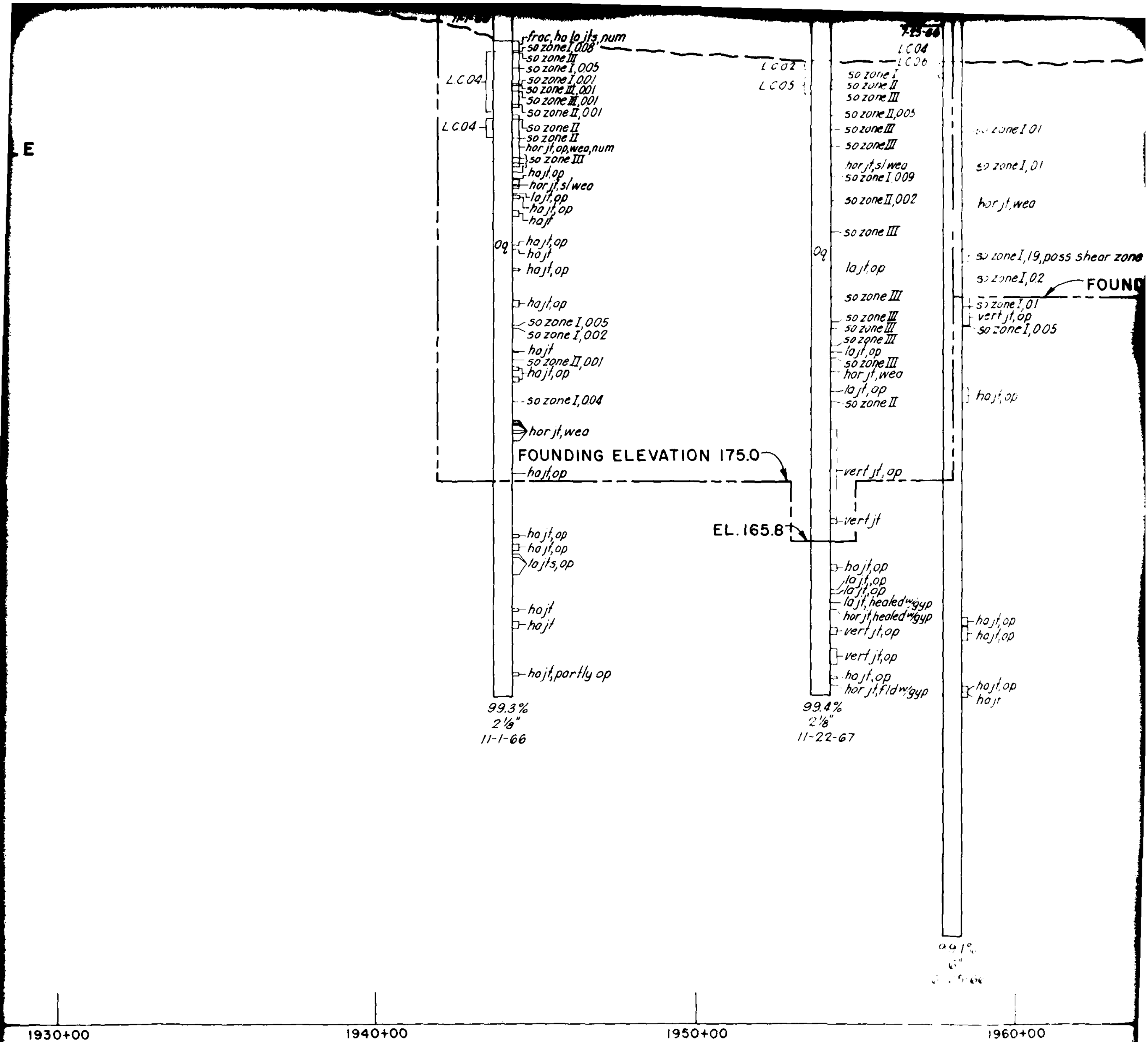
GUIDE WALL
LOCK 1-5
NOTE: TOP OF LOCK WA
TION 286.7
MATE TOP OF ROCK
RC-66503
780' LT
AUDC-67515
280' LT
RC-66501
810' LT
OB
Oq
LC04
LC02
LC05
LC06
frac, ho lo jts, num
so zone I, .008'
so zone III
so zone I, .005
so zone I, .001
so zone III, .001
so zone II, .001
hor jt, op, wea, num
hor jt, sl wea
so zone II, .005
so zone I, .009
so zone II, .002
so zone I, 01
hor jt, wea
so zone I, 19, poss shear zone
so zone I, 02
FOUNDING EL
vert jt, op
so zone I, .005
so zone I, .002
so zone II, .001
so zone I, .004
hor jt, wea
FOUNDING ELEVATION 175.0
EL. 165.8
lo jt, healed w gyp
hor jt, healed w gyp
hor jt, fld w gyp
ho jt, partly op
QUE
99.3%
2 1/8"
11-1-66
99.4%
2 1/8"
11-22-67
99.1%



NOTE: TOP OF LOCK WALL ELEVATION IS 331.7
LOWER GUIDE WALL
AUDC-67515
280' LT
RC-66501
810' LT
LAKE ONTARIO
QUEENSTON SHALE
FOUNDING ELEVATION 204.0
OB
LC02
LC05
LC04
LC06
so zone I
so zone II
so zone III
so zone II, 005
hor jt, sl wea
so zone I, 009
so zone II, 002
la jt op
hor jt, wea
so zone I, 19, poss shear zone
so zone I, 02
so zone I, 01
vert jt, op
so zone I, 005
ho jt, op
vert jt, op
vert jt
165.8
la jt, healed w gyp
hor jt, healed w gyp
hor jt, fld w gyp
99.4%
11-22-67
11-23-67
7-25-66
99.1%
6"
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100



ELEVATION IN FEET I.G.L.D. (1955)
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
QUEENSTON SHALE
Oq
lo jt, op
bdd plns, wea
lo jt, op
ho jt, op
so zone III
ho jt, op
lo jt, op
bdd pln, wea
ho jt, op
ho jt, op
lo jt, op
L.C. 0.1
so zone II, 0.2
ho jt, op
ho jt, op
ho jt, op
so zone III
ho jt, op
lo jt, op
ho jt, op
lo jt, op
so zone III
99.9%
2'8"
10-27-66
1910+00
1920+00
1930+00



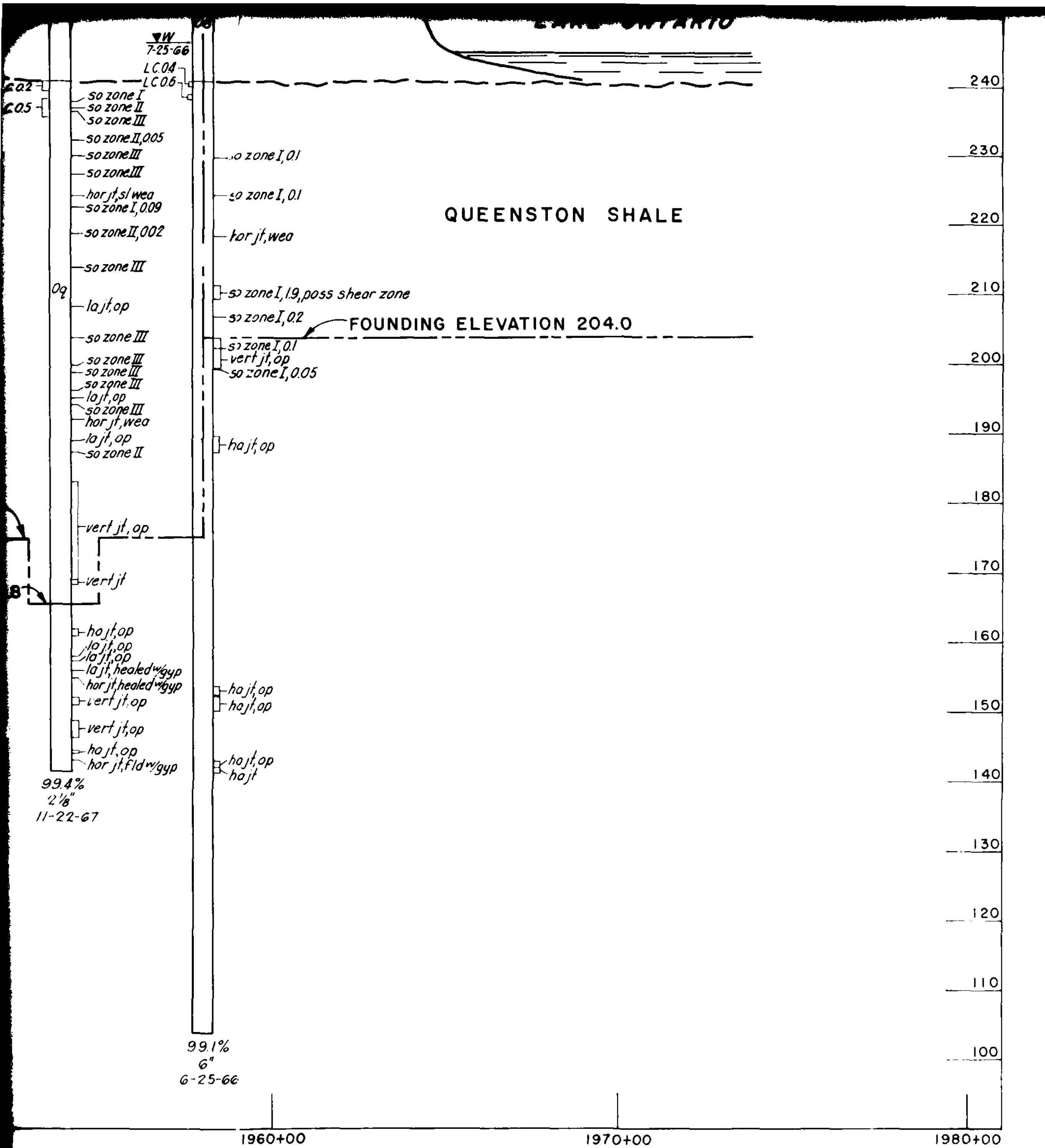
PROFILE A-A

NOTES:

FOR LOCATION OF PROFILE AND BORINGS, SEE PLATE B5.

FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS, JOINT CLASSIFICATIONS AND SOFT ZONE CLASSIFICATION SEE PLATE B1.

FOR DETAILED DESCRIPTION OF OVERBURDEN SEE PLATE B18.



B5.
OGIC
NS

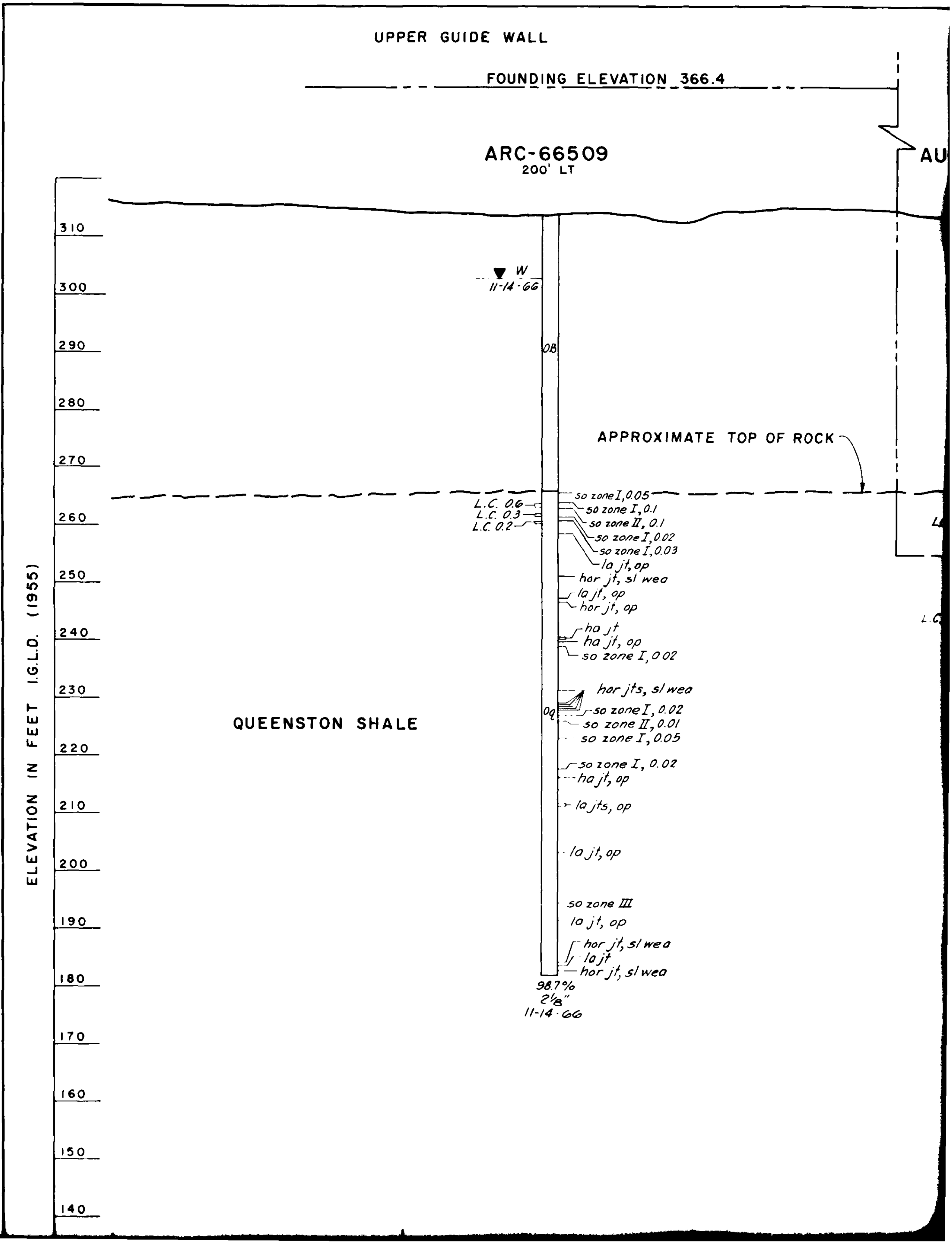
PLATE B18.

LAKE ERIE-LAKE ONTARIO WATERWAY

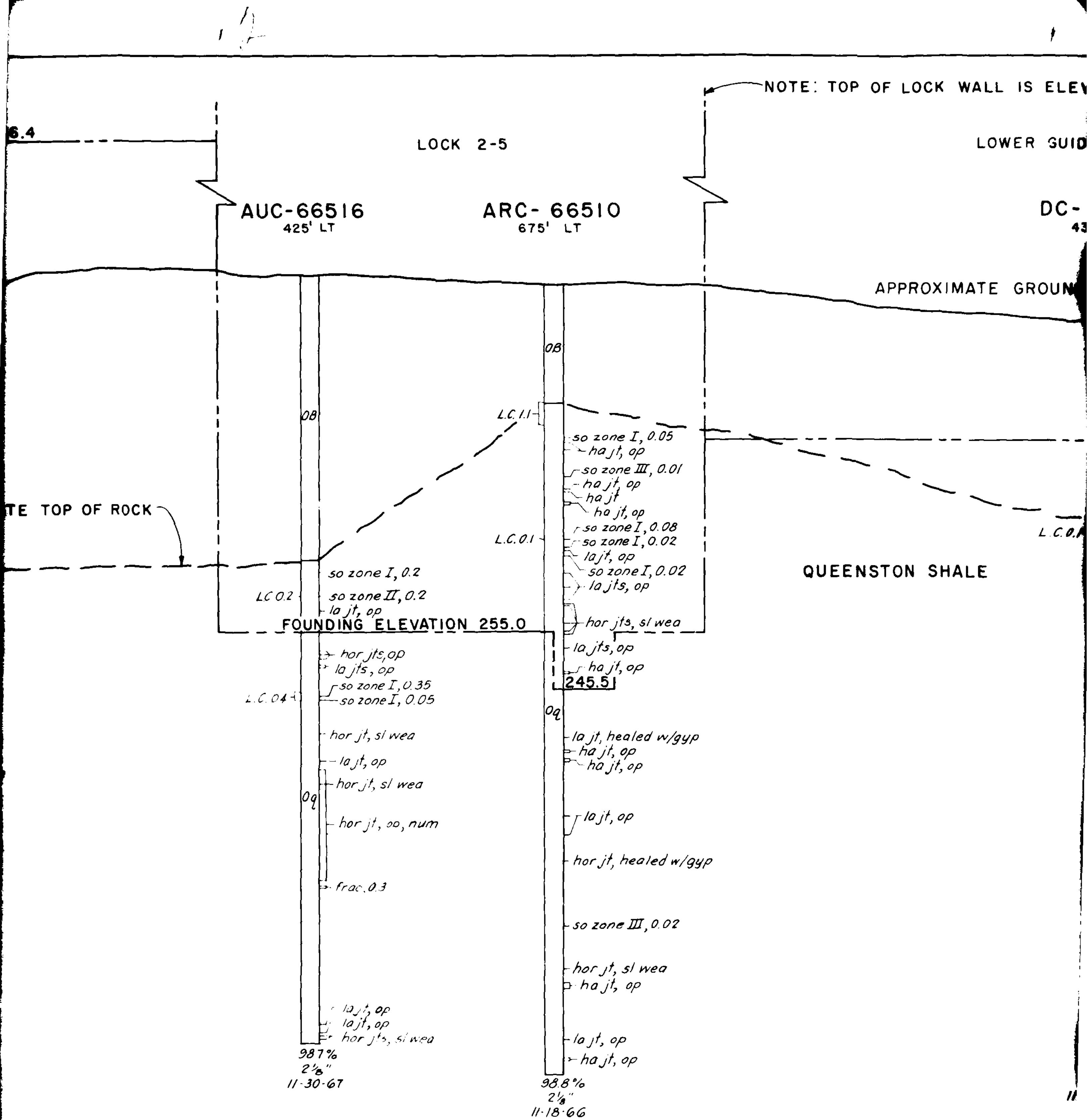
GEOLOGIC PROFILE
LOCK 1-5

U. S. ARMY ENGINEER DISTRICT, BUFFALO

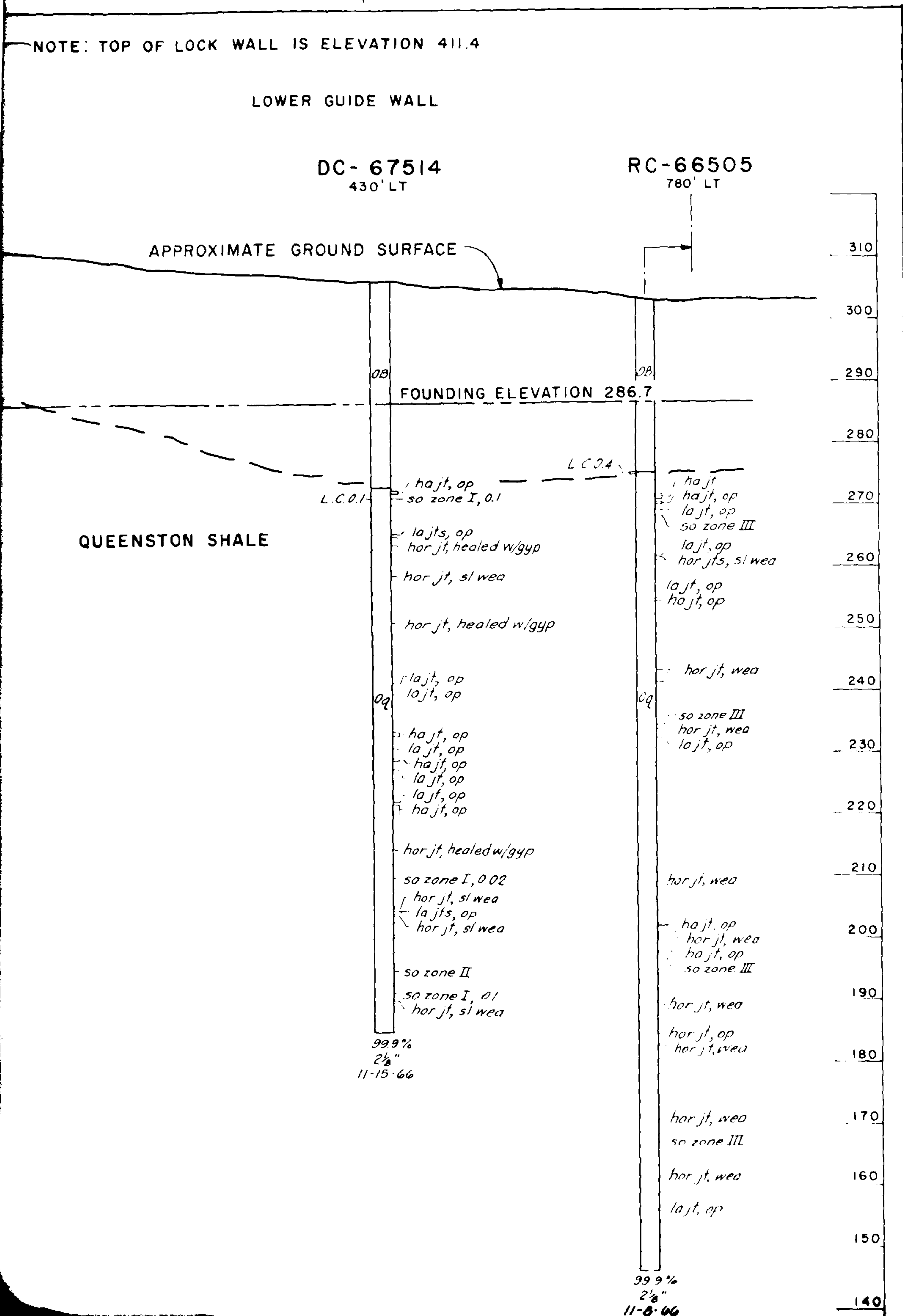
TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

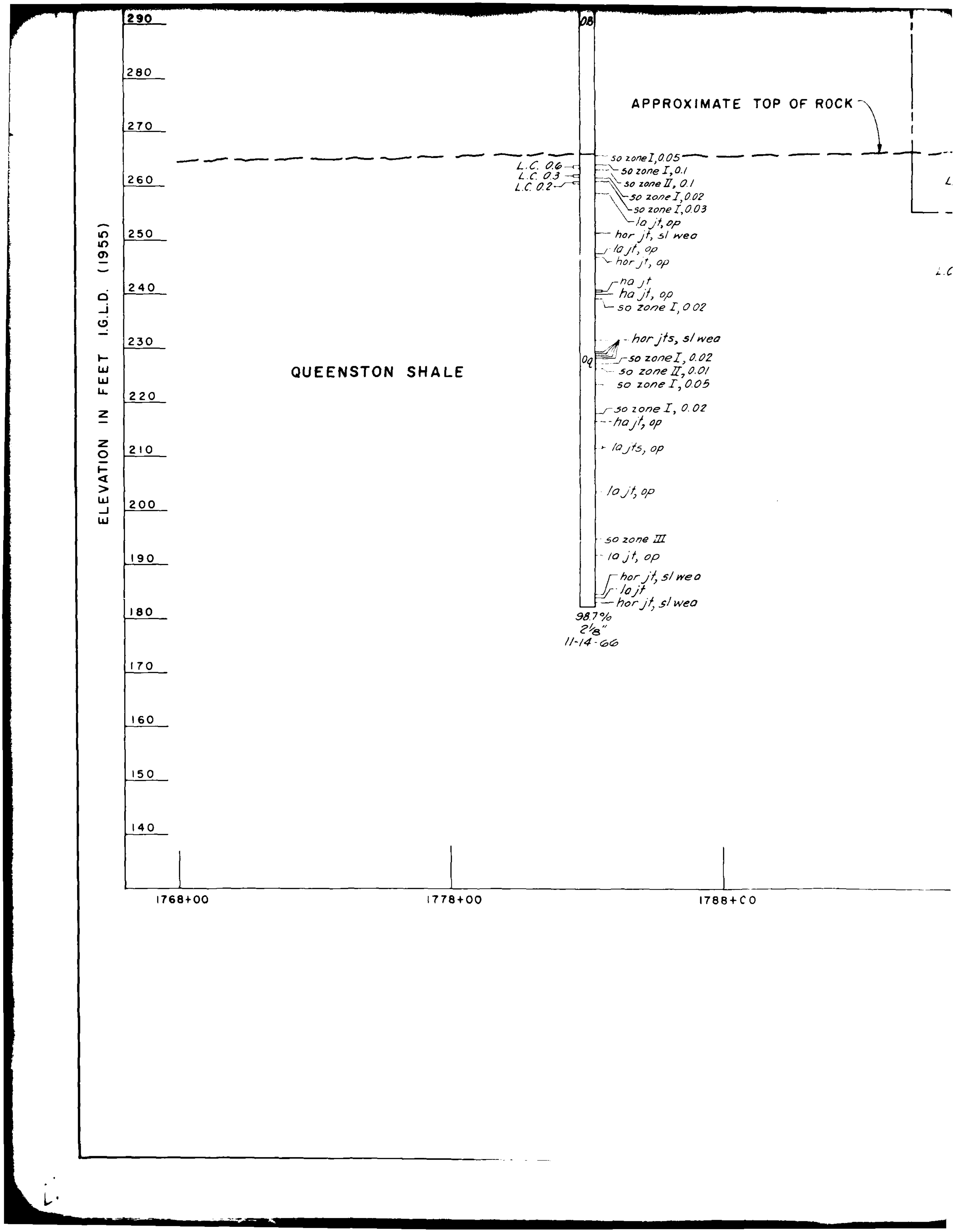


UPPER GUIDE WALL
FOUNDING ELEVATION 366.4
ARC-66509
200' LT
AU
ELEVATION IN FEET I.G.L.D. (1955)
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
W
11-14-66
OB
APPROXIMATE TOP OF ROCK
QUEENSTON SHALE
L.C. 0.6
L.C. 0.3
L.C. 0.2
so zone I, 0.05
so zone I, 0.1
so zone II, 0.1
so zone I, 0.02
so zone I, 0.03
la jt, op
hor jt, sl wea
la jt, op
hor jt, op
ha jt
ha jt, op
so zone I, 0.02
hor jts, sl wea
Oq
so zone I, 0.02
so zone II, 0.01
so zone I, 0.05
so zone I, 0.02
ha jt, op
la jts, op
la jt, op
so zone III
la jt, op
hor jt, sl wea
la jt
hor jt, sl wea
98.7%
2 1/8"
11-14-66



NOTE: TOP OF LOCK WALL IS ELEV
6.4
LOCK 2-5
LOWER GUID
AUC-66516
425' LT
ARC- 66510
675' LT
DC-
43
APPROXIMATE GROUN
OB
L.C. 1.1
so zone I, 0.05
ha jt, op
so zone III, 0.01
ha jt, op
ha jt
ha jt, op
TE TOP OF ROCK
L.C. 0.1
so zone I, 0.08
so zone I, 0.02
la jt, op
so zone I, 0.02
la jts, op
L.C. 0.
QUEENSTON SHALE
so zone I, 0.2
LC 0.2
so zone II, 0.2
la jt, op
FOUNDING ELEVATION 255.0
hor jts, sl wea
la jts, op
ha jt, op
245.5
hor jts, op
la jts, op
so zone I, 0.35
L.C. 0.4
so zone I, 0.05
Oq
hor jt, sl wea
la jt, healed w/gyp
ha jt, op
ha jt, op
la jt, op
hor jt, sl wea
hor jt, op, num
la jt, op
hor jt, healed w/gyp
frac. 0.3
so zone III, 0.02
hor jt, sl wea
ha jt, op
la jt, op
la jt, op
hor jts, sl wea
98.7%
2 1/8"
11-30-67
la jt, op
ha jt, op
98.8%
2 1/8"
11-18-66


NOTE: TOP OF LOCK WALL IS ELEVATION 411.4
LOWER GUIDE WALL
DC- 67514
430' LT
RC-66505
780' LT
APPROXIMATE GROUND SURFACE
OB
OB
FOUNDING ELEVATION 286.7
L.C.0.4
L.C.0.1
QUEENSTON SHALE
ha jt, op
so zone I, 0.1
la jts, op
hor jt, healed w/gyp
hor jt, sl wea
hor jt, healed w/gyp
la jt, op
la jt, op
Oq
ha jt, op
la jt, op
ha jt, op
la jt, op
la jt, op
ha jt, op
hor jt, healed w/gyp
so zone I, 0.02
hor jt, sl wea
la jts, op
hor jt, sl wea
so zone II
so zone I, 0.1
hor jt, sl wea
99.9%
2⅛"
11-15-66
ha jt
ha jt, op
la jt, op
so zone III
la jt, op
hor jts, sl wea
la jt, op
ha jt, op
hor jt, wea
Oq
so zone III
hor jt, wea
la jt, op
hor jt, wea
ha jt, op
hor jt, wea
ha jt, op
so zone III
hor jt, wea
hor jt, op
hor jt, wea
hor jt, wea
so zone III
hor jt, wea
la jt, op
99.9%
2⅛"
11-8-66
310
300
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140



ELEVATION IN FEET I.G.L.D. (1955)
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
APPROXIMATE TOP OF ROCK
QUEENSTON SHALE
OB
OQ
L.C. 0.6
L.C. 0.3
L.C. 0.2
so zone I, 0.05
so zone I, 0.1
so zone II, 0.1
so zone I, 0.02
so zone I, 0.03
la jt, op
hor jt, sl wea
la jt, op
hor jt, op
ha jt
ha jt, op
so zone I, 0.02
hor jts, sl wea
so zone I, 0.02
so zone II, 0.01
so zone I, 0.05
so zone I, 0.02
ha jt, op
la jts, op
la jt, op
so zone III
la jt, op
hor jt, sl wea
la jt
hor jt, sl wea
98.7%
2 1/8"
11-14-66
1768+00
1778+00
1788+00

AD-A100 739 CORPS OF ENGINEERS BUFFALO N Y BUFFALO DISTRICT F/G 13/2

REVIEW OF REPORTS ON LAKE ERIE-LAKE ONTARIO WATERWAY, NEW YORK.--ETC(U)

OCT 73

UNCLASSIFIED NL

3 OF 3

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END

DATE FILMED

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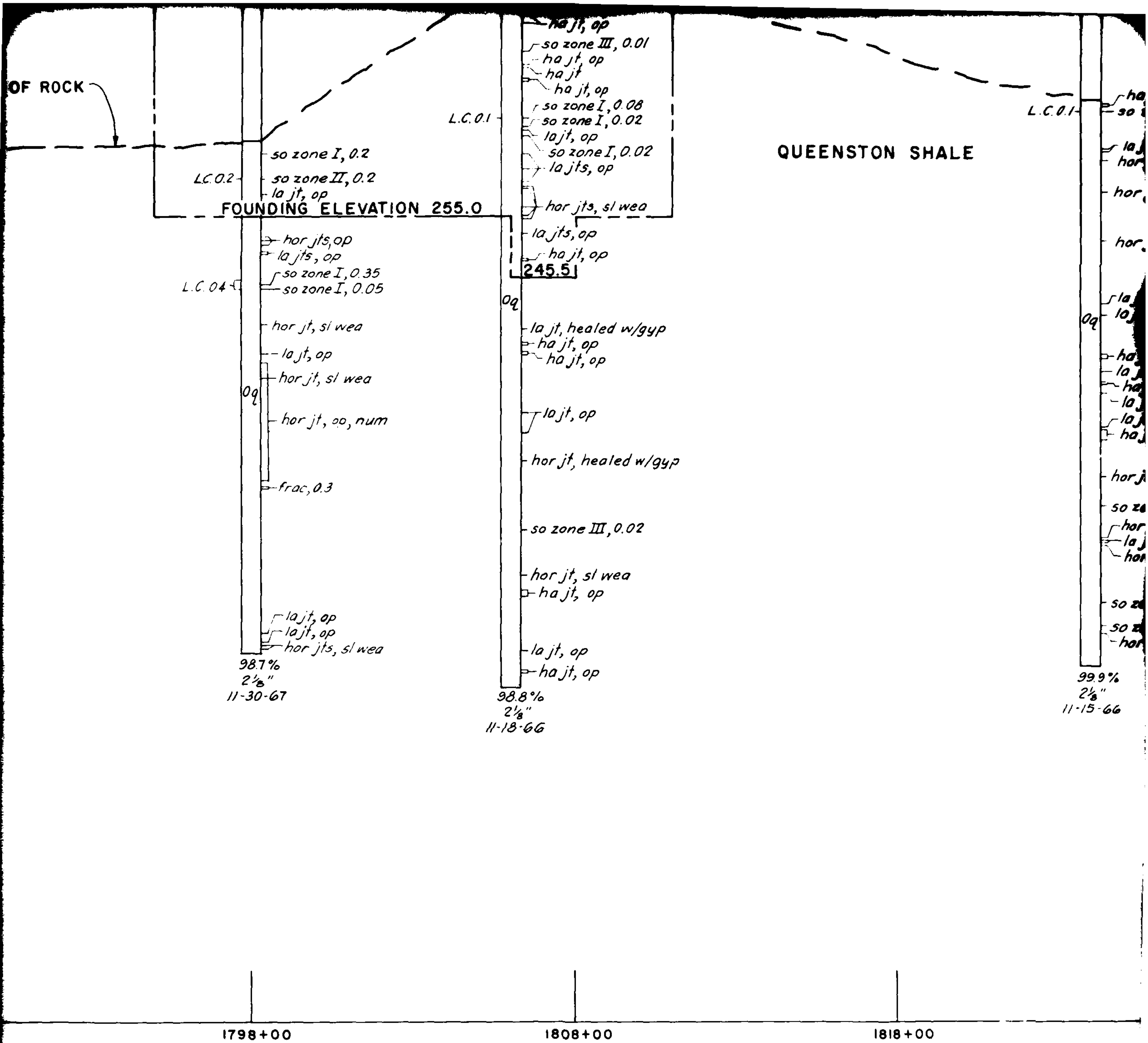


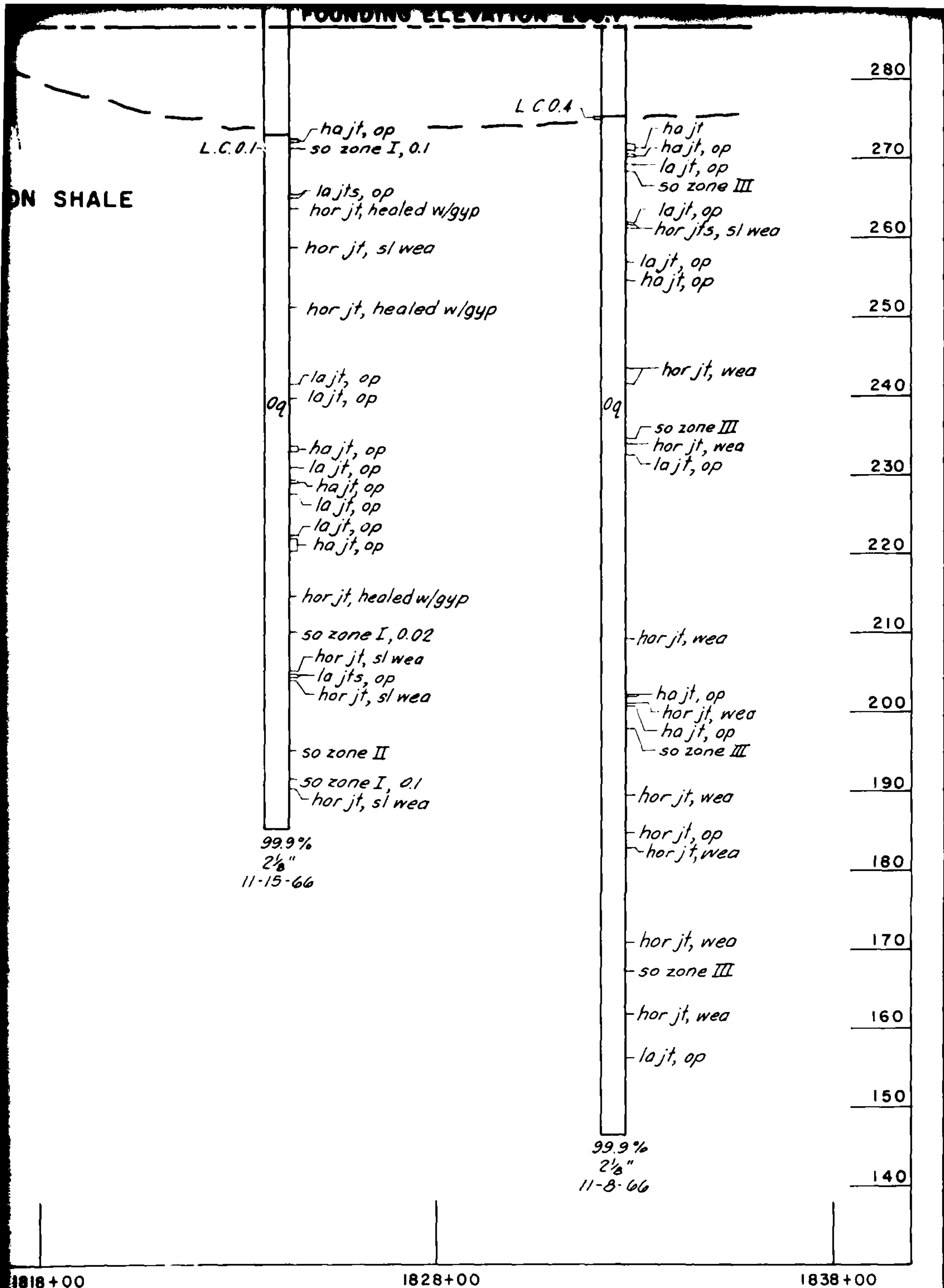
PROFILE B-B

NOTES:

FOR LOCATION OF PROFILE AND BORINGS SEE PLATE B4.

FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS, SOFT ZONE CLASSIFICATION SEE PLATE B1.

FOR DETAILED DESCRIPTION OF OVERBURDEN SEE PLATE B17.



D BORINGS SEE
S, GENERALIZED
VIATIONS, SOFT
BI.
OF OVERBURDEN

LAKE ERIE-LAKE ONTARIO WATERWAY

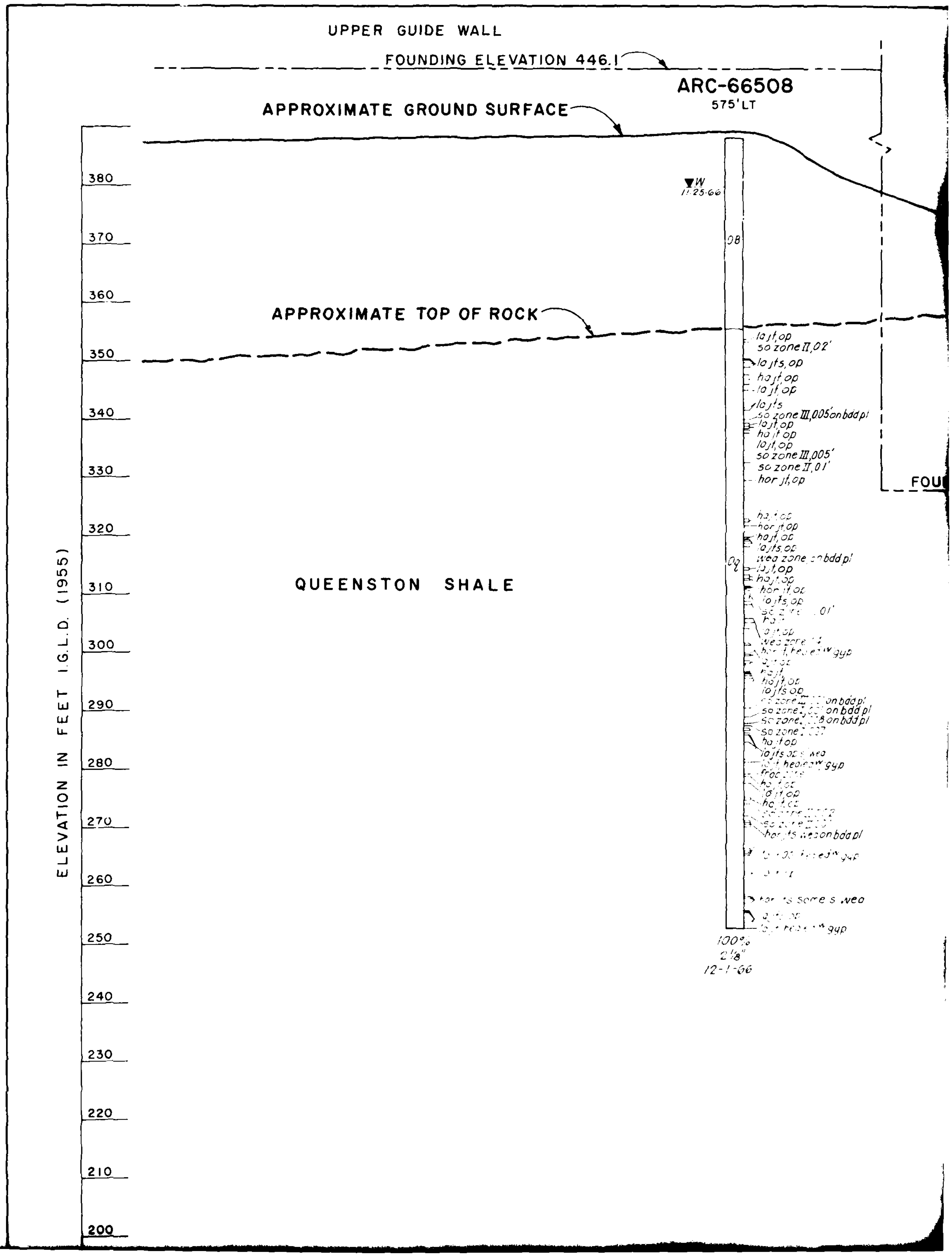
GEOLOGIC PROFILE
LOCK 2-5

U. S. ARMY ENGINEER DISTRICT, BUFFALO

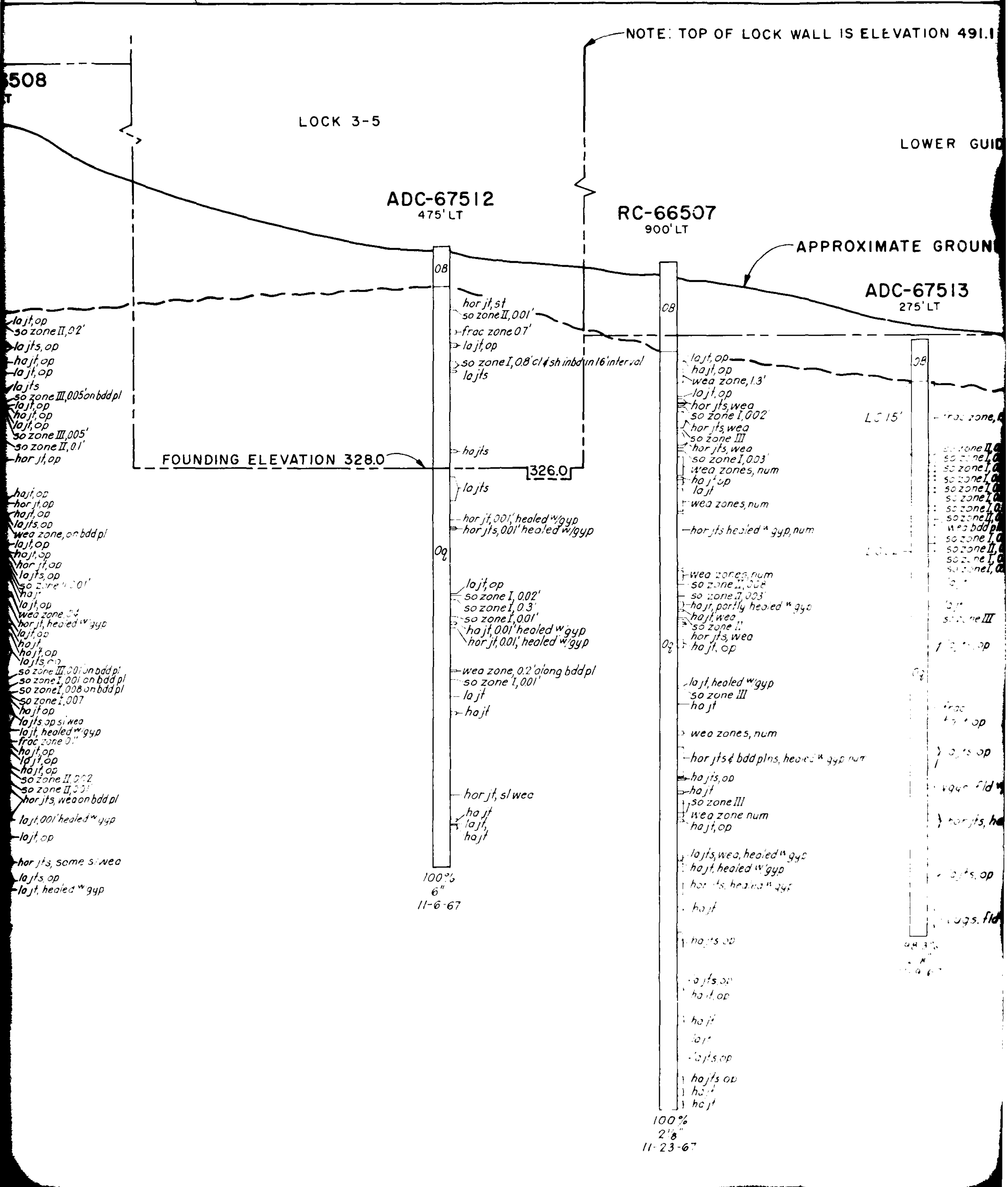
TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

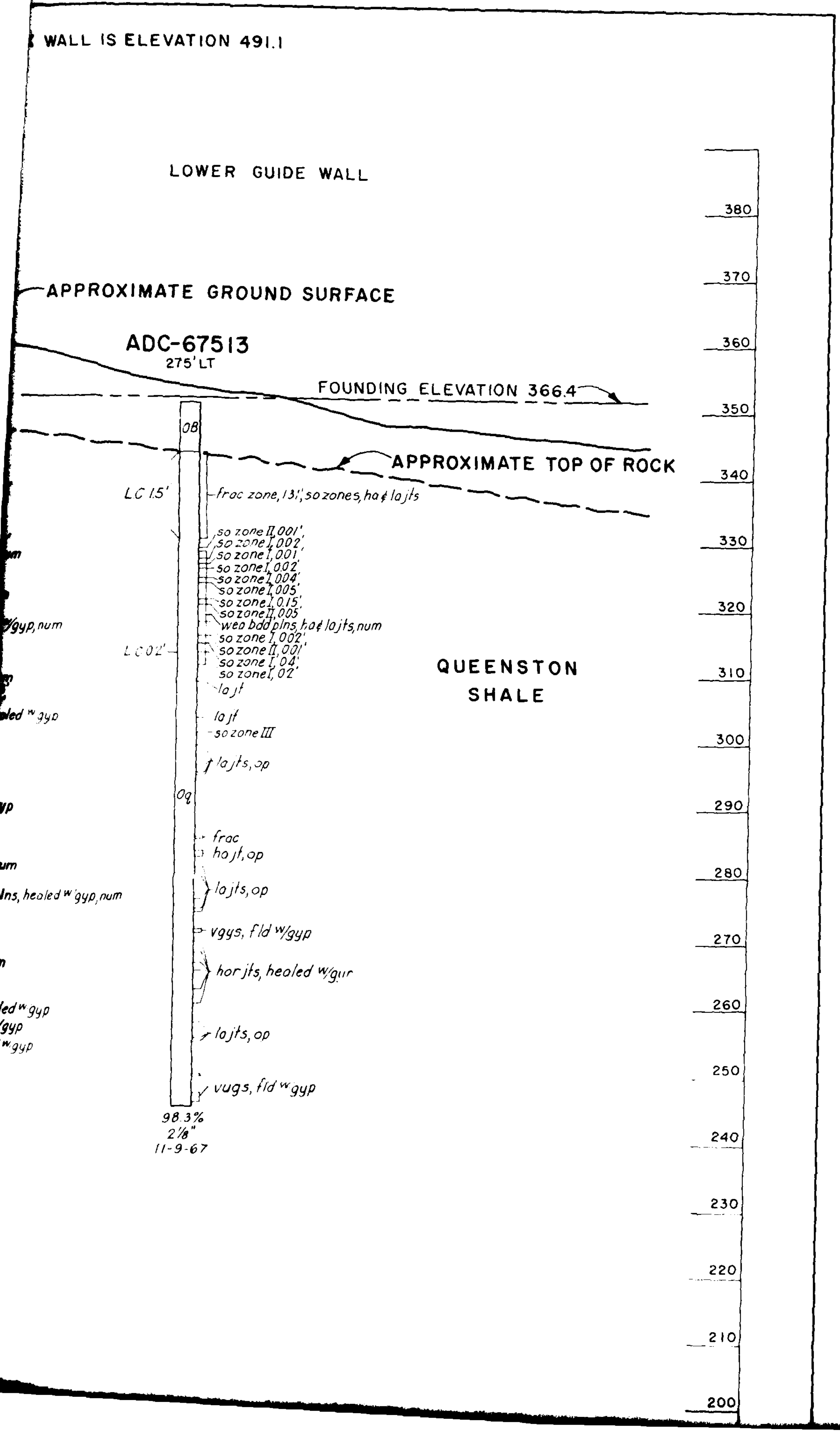
PLATE B21

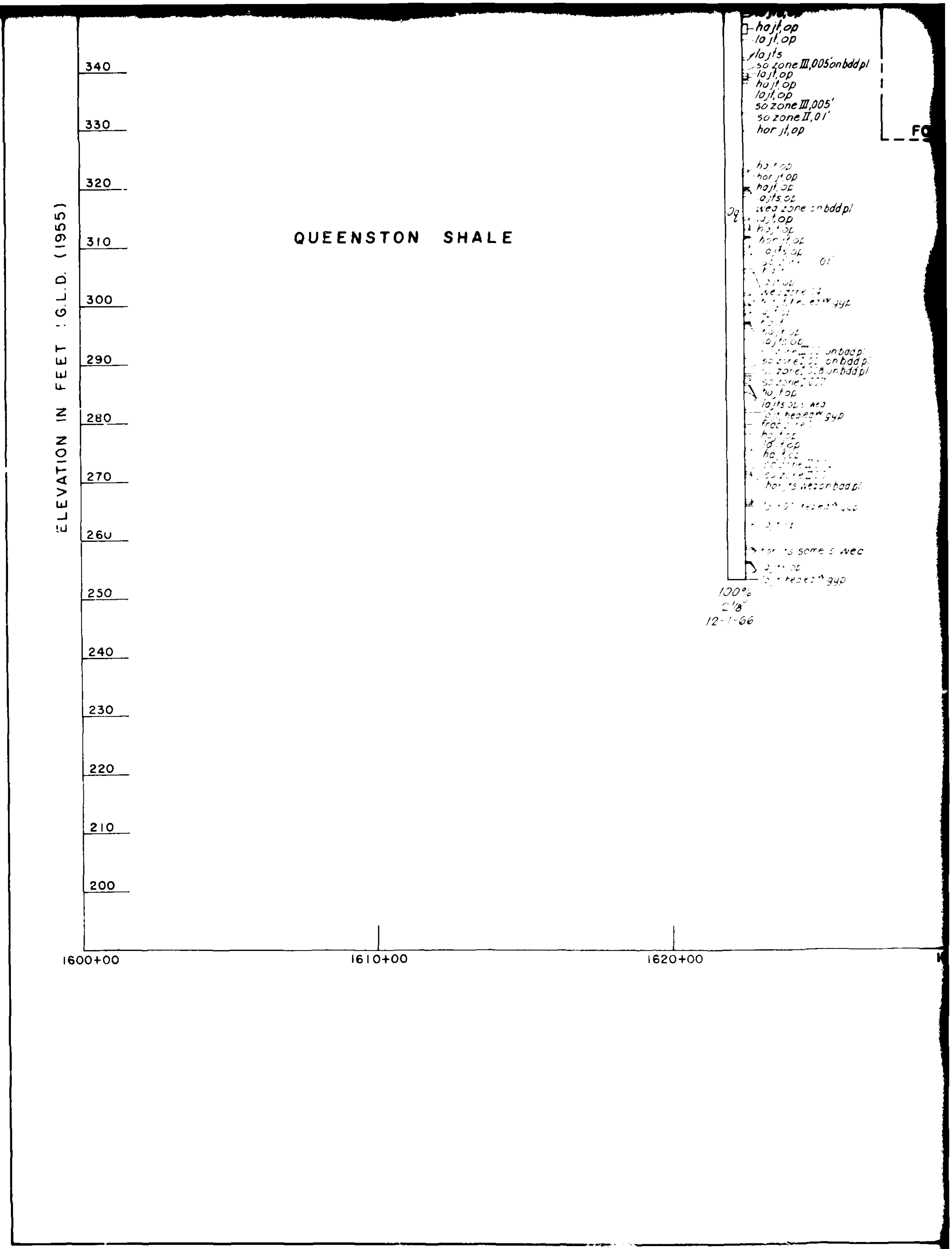
16



UPPER GUIDE WALL
FOUNDING ELEVATION 446.1
ARC-66508
575'LT
APPROXIMATE GROUND SURFACE
APPROXIMATE TOP OF ROCK
QUEENSTON SHALE
ELEVATION IN FEET I.G.L.D. (1955)
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
W
11-25-66
OB
Qq
lo jt, op
so zone II, .02'
lo jts, op
ho jt, op
lo jt, op
lo jts
so zone III, .005' on bdd pl
lo jt, op
ho jt op
lo jt, op
so zone III, .005'
so zone II, .01'
hor jt, op
100%
2 1/8"
12-1-66
FOU

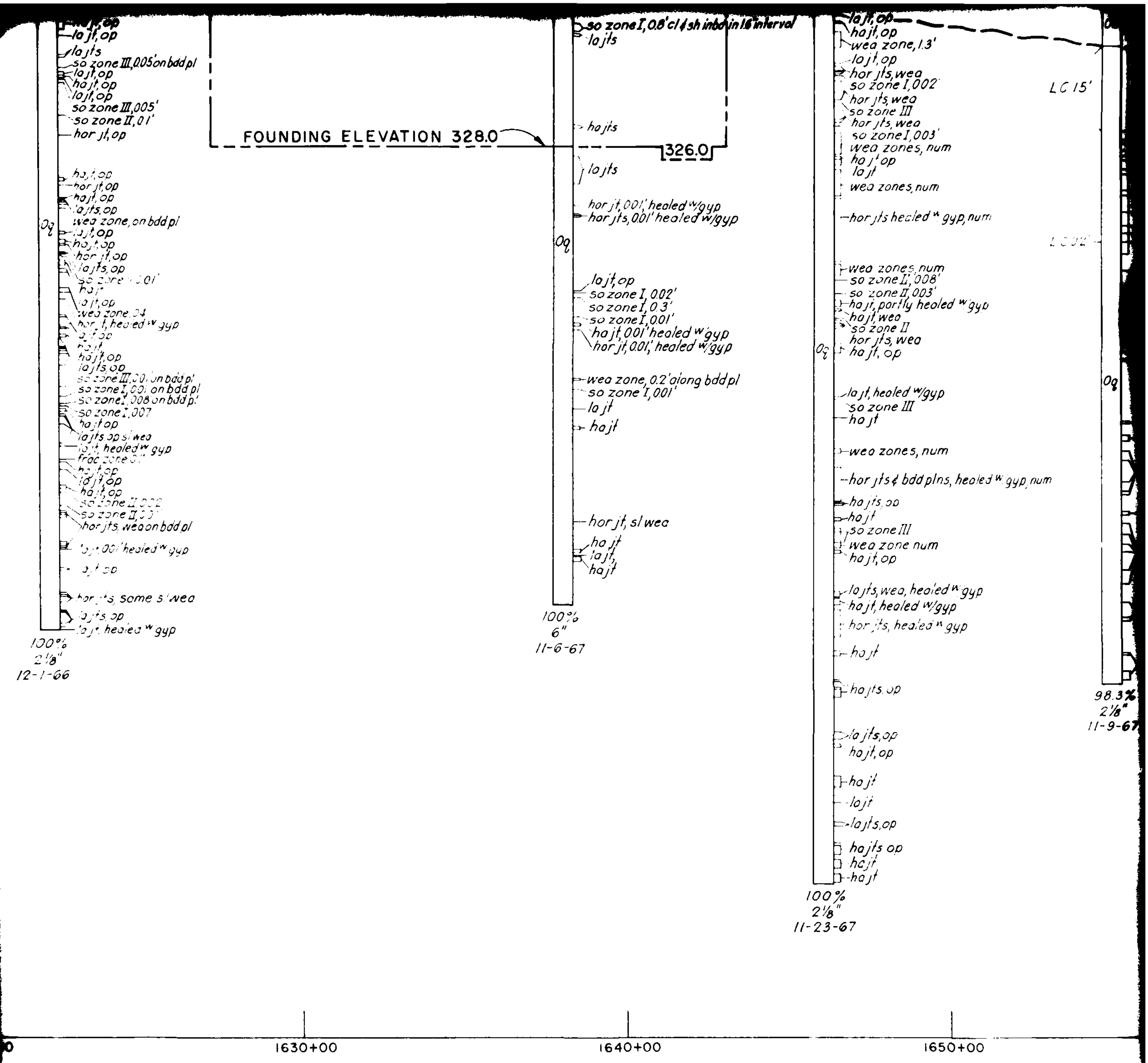

NOTE: TOP OF LOCK WALL IS ELEVATION 491.1
508
LOCK 3-5
LOWER GUID
ADC-67512
475' LT
RC-66507
900' LT
APPROXIMATE GROUN
ADC-67513
275' LT
FOUNDING ELEVATION 328.0
326.0
OB
Oq
hor jt, st
so zone II, 0.01'
frac zone 0.7'
la jt, op
so zone I, 0.8' cl & sh inbd in 16' interval
la jts
ha jts
la jts
hor jt, 0.01' healed w/gyp
hor jts, 0.01' healed w/gyp
la jt, op
so zone I, 0.02'
so zone I, 0.3'
so zone I, 0.01'
ha jt, 0.01' healed w/gyp
hor jt, 0.01', healed w/gyp
wea zone, 0.2' along bdd pl
so zone I, 0.01'
la jt
ha jt
hor jt, sl wea
ha jt
la jt,
ha jt
100%
6"
11-6-67
la jt, op
ha jt, op
wea zone, 1.3'
la jt, op
hor jts, wea
so zone I, 0.002'
hor jts, wea
so zone III
hor jts, wea
so zone I, 0.03'
wea zones, num
ha jt, op
la jt
wea zones, num
hor jts healed w gyp, num
wea zones, num
ha jt, wea
hor jts, wea
ha jt, op
la jt, healed w/gyp
so zone III
ha jt
wea zones, num
hor jts & bdd plns, healed w gyp num
ha jts, op
ha jt
so zone III
wea zone num
ha jt, op
la jts, wea, healed w gyp
ha jt, healed w/gyp
ha jt
ha jts op
la jts op
ha jt, op
ha jt
la jt
la jts op
ha jts op
ha jt
ha jt
100%
2 1/8"
11-23-67
la jt, op
so zone II, 0.2'
la jts, op
ha jt, op
la jt, op
la jts
so zone III, 0.005' on bdd pl
la jt, op
ha jt, op
la jt, op
so zone III, 0.005'
so zone II, 0.1'
hor jt, op
ha jt, op
hor jt, op
ha jt, op
la jts, op
wea zone, on bdd pl
la jt, op
ha jt, op
hor jt, op
la jts, op
la jt, op
hor jt, healed w gyp
so zone III, 0.01 on bdd pl
so zone I, 0.01 on bdd pl
so zone I, 0.08 on bdd pl
so zone I, 0.07
ha jt op
la jts op sl wea
la jt, healed w gyp
ha jt, op
la jt, op
ha jt, op
hor jts, wea on bdd pl
la jt, 0.01' healed w gyp
la jt, op
hor jts, some sl wea
la jts, op
la jt, healed w gyp
LC 15'


WALL IS ELEVATION 491.1
LOWER GUIDE WALL
APPROXIMATE GROUND SURFACE
ADC-67513
275' LT
FOUNDING ELEVATION 366.4
APPROXIMATE TOP OF ROCK
OB
LC 1.5'
frac zone, 1.3', so zones, ha & la jts
so zone II, .001'
so zone I, .002'
so zone I, .001'
so zone I, .002'
so zone I, .004'
so zone I, .005'
so zone I, 0.15'
so zone II, .005'
wea bdd plns, ha & la jts, num
so zone I, .002'
LC 0.2'
so zone II, .001'
so zone I, .04'
so zone I, .02'
la jt
la jt
so zone III
la jts, op
Oq
frac
ha jt, op
la jts, op
vgys, fld w/gyp
hor jts, healed w/gyp
la jts, op
vugs, fld w/gyp
98.3%
2 7/8"
11-9-67
QUEENSTON
SHALE
380
370
360
350
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
w/gyp, num
healed w gyp
plns, healed w gyp, num
healed w gyp
w/gyp
d w gyp



ELEVATION IN FEET I.G.L.D. (1955)
340
330
320
310
300
290
280
270
260
250
240
230
220
210
200
QUEENSTON SHALE
ho jt, op
lo jt, op
lo jts
so zone III, .005' on bdd pl
lo jt, op
ho jt, op
lo jt, op
so zone III, .005'
so zone II, .01'
hor jt, op
Oq
100%
2 1/8"
12-1-66
1600+00
1610+00
1620+00

4



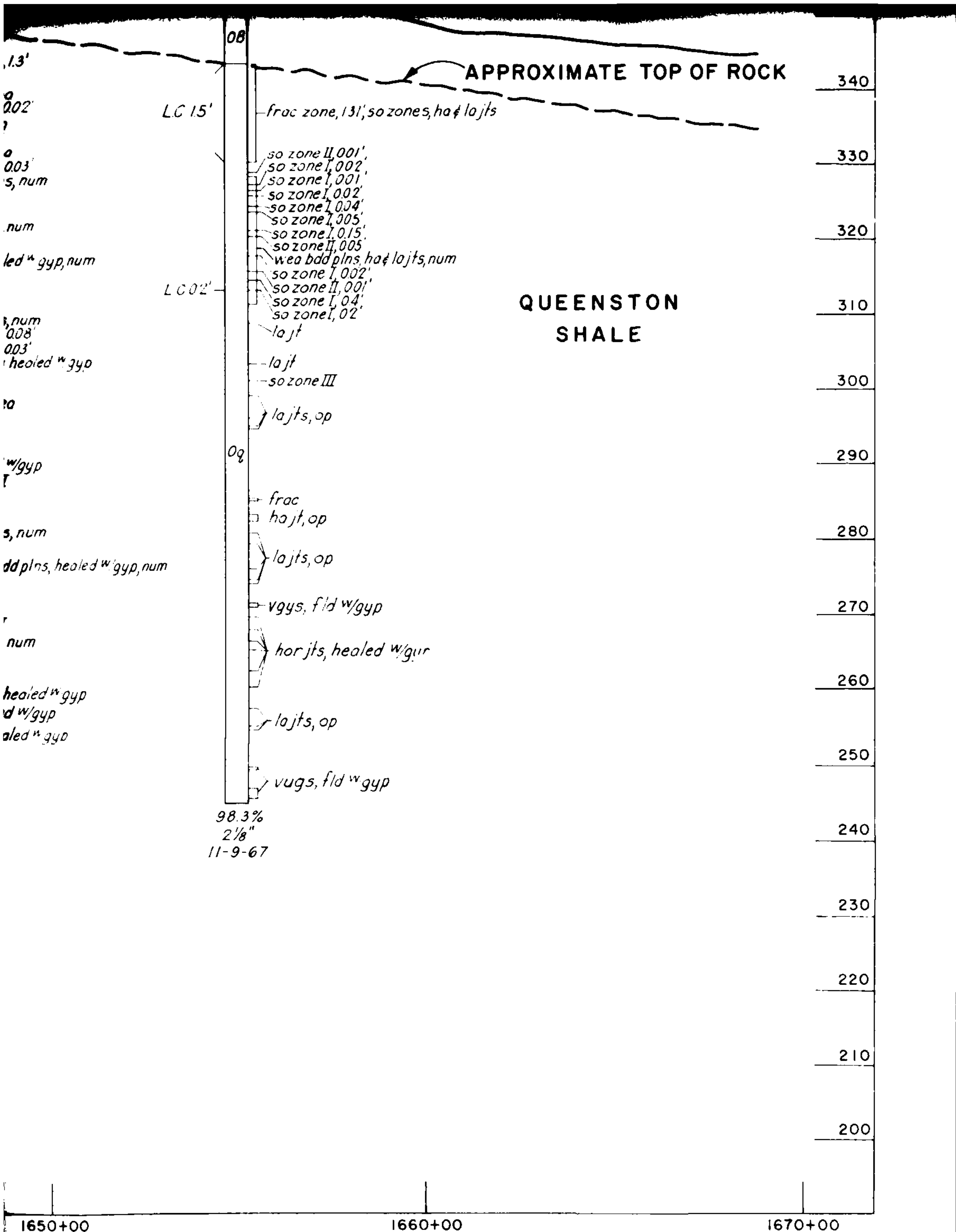
PROFILE C-C

NOTES:

FOR LOCATION OF PROFILE AND BORINGS SEE PLATE B4.

FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS JOINT CLASSIFICATION AND SOFT ZONE CLASSIFICATION SEE PLATE B1.

FOR DETAILED DESCRIPTION OF OVERBURDEN SEE PLATES B15 AND B16.



FILE AND BORINGS SEE

RATIONS, GENERALIZED
ABBREVIATIONS JOINT
ONE CLASSIFICATION SEE

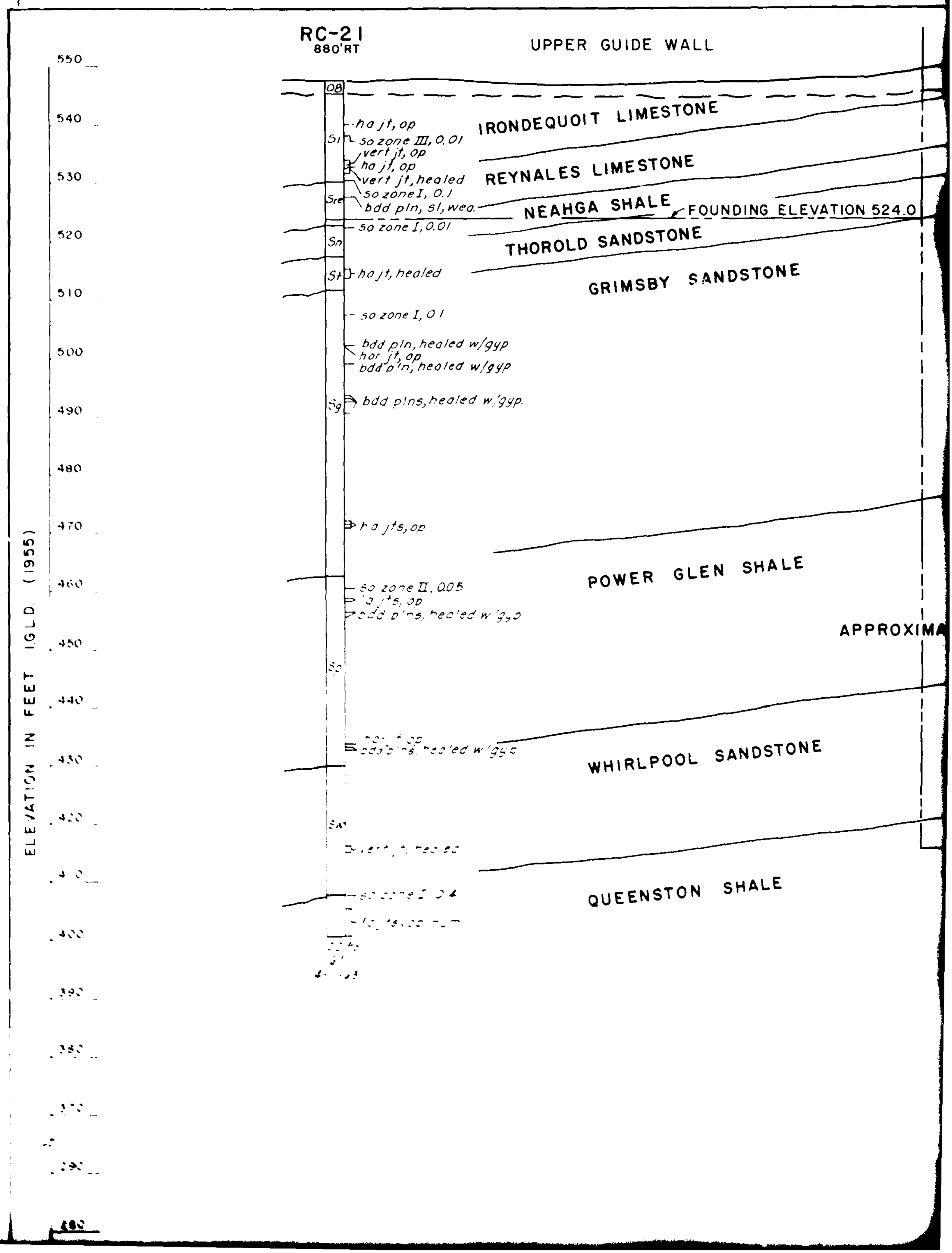
TION OF OVERBURDEN

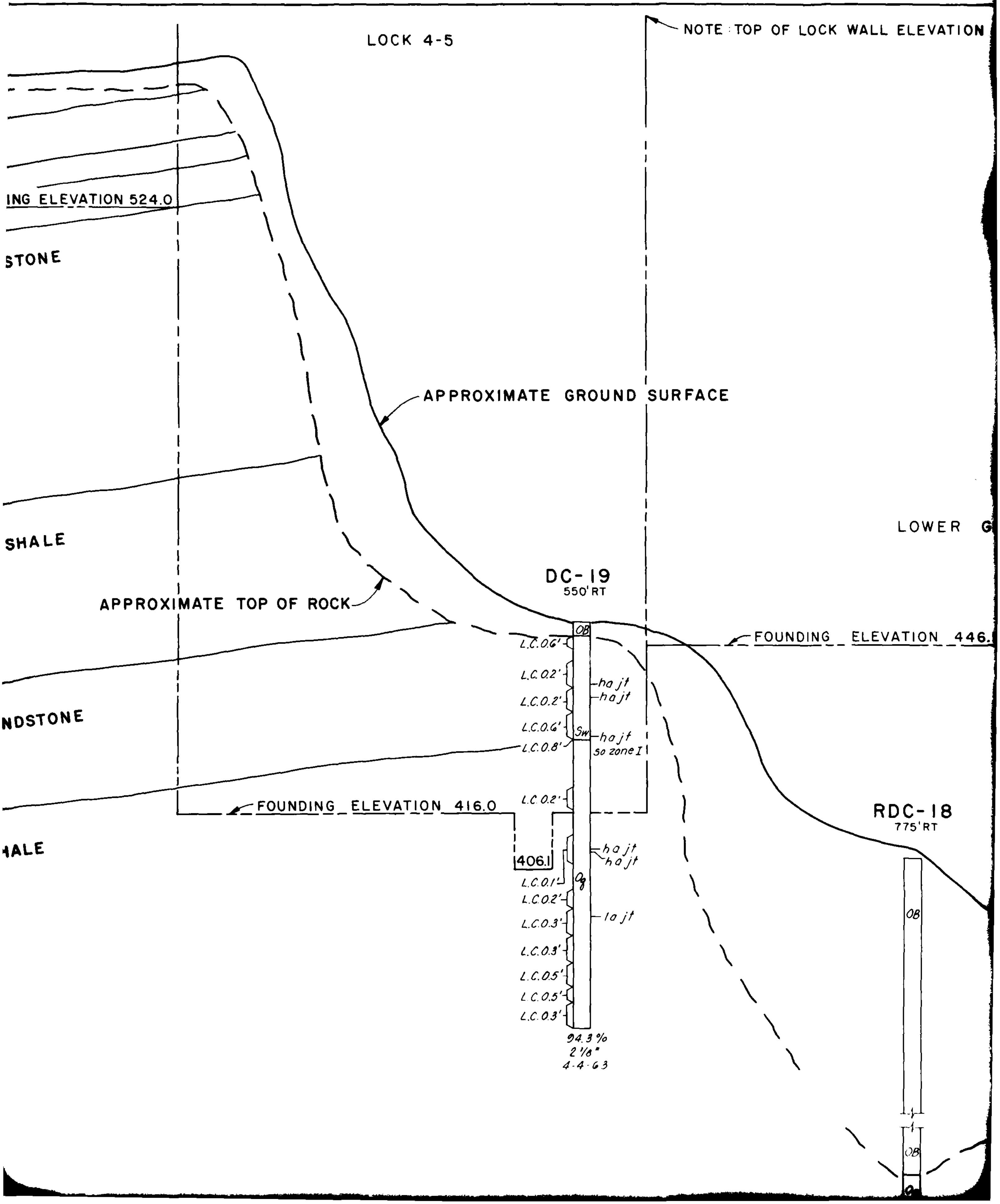
LAKE ERIE-LAKE ONTARIO WATERWAY

GEOLOGIC PROFILE
LOCK 3-5

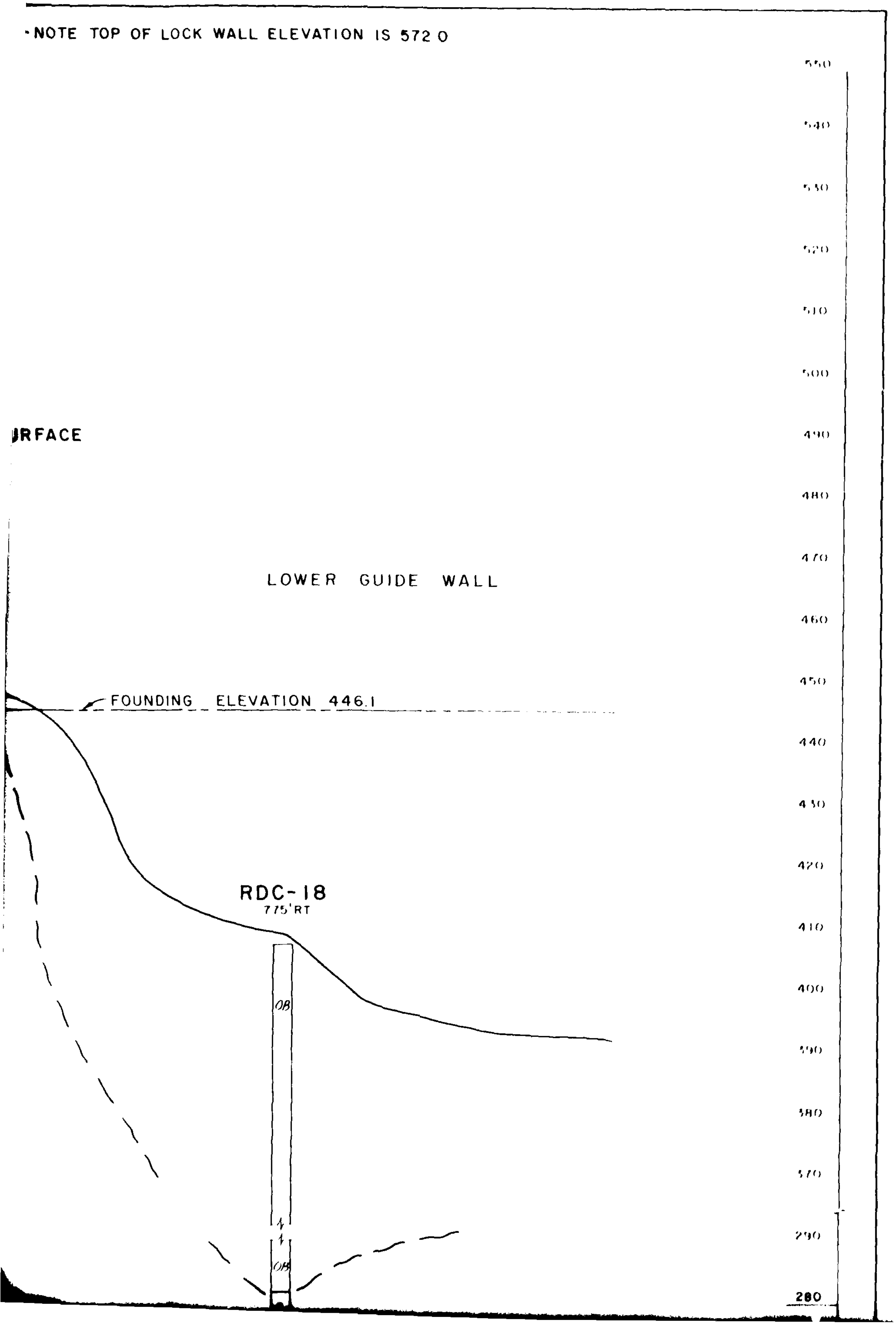
U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

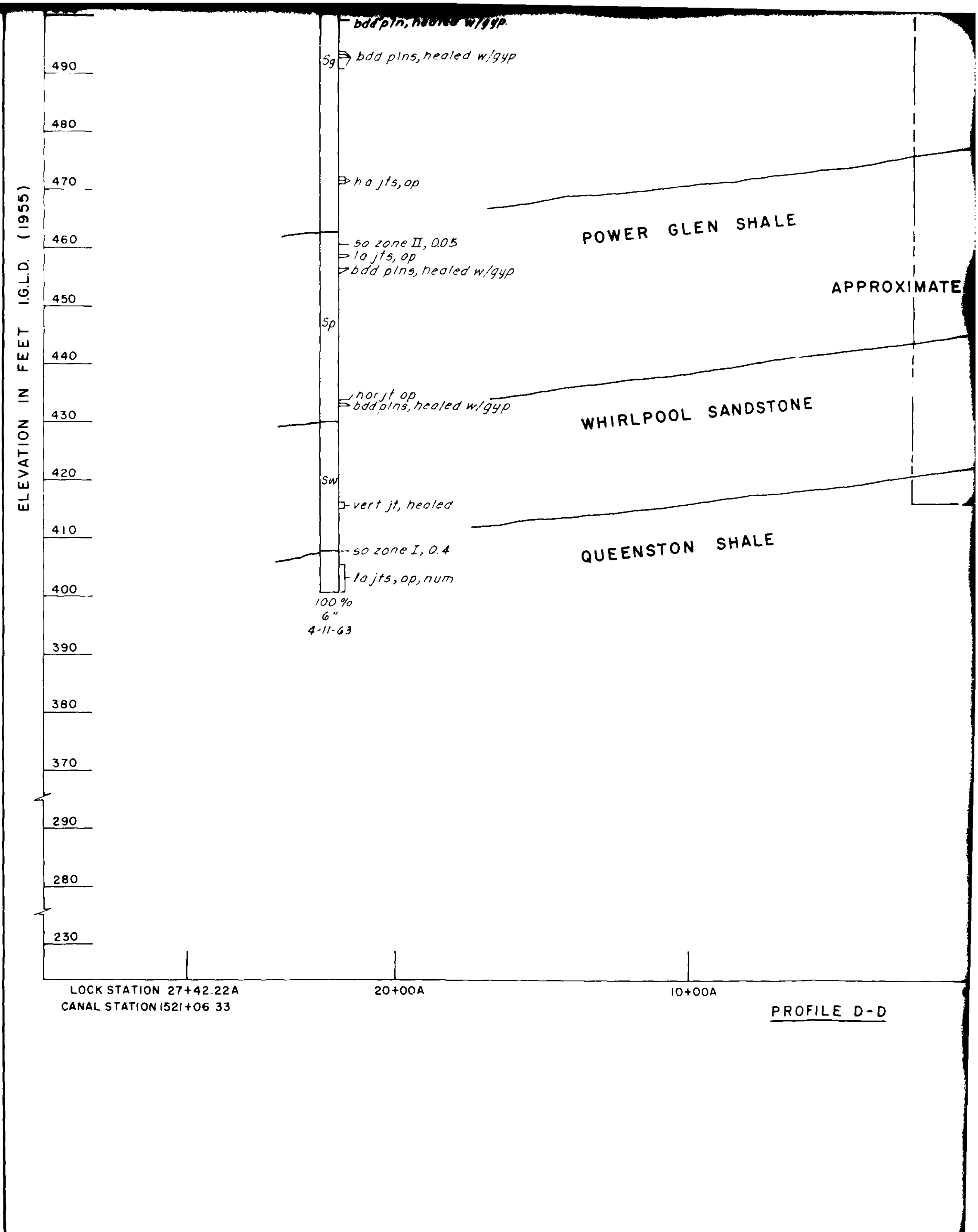

RC-21
880'RT
UPPER GUIDE WALL
ELEVATION IN FEET IGLD (1955)
550
540
530
520
510
500
490
480
470
460
450
440
430
420
400
OB
Si
Sre
Sn
St
Sg
ha jt, op
so zone III, 0.01
vert jt, op
ha jt, op
vert jt, healed
so zone I, 0.1
bdd pln, sl, wea.
so zone I, 0.01
ha jt, healed
so zone I, 0.1
bdd pln, healed w/gyp
hor jt, op
bdd pln, healed w/gyp
bdd plns, healed w/gyp.
ha jts, op
so zone II, 0.05
IRONDEQUOIT LIMESTONE
REYNALES LIMESTONE
NEAHGA SHALE
FOUNDING ELEVATION 524.0
THOROLD SANDSTONE
GRIMSBY SANDSTONE
POWER GLEN SHALE
APPROXIMA
WHIRLPOOL SANDSTONE
QUEENSTON SHALE



LOCK 4-5
NOTE: TOP OF LOCK WALL ELEVATION
ING ELEVATION 524.0
STONE
APPROXIMATE GROUND SURFACE
LOWER G
SHALE
APPROXIMATE TOP OF ROCK
DC-19
550' RT
OB
FOUNDING ELEVATION 446.
L.C. 0.6'
L.C. 0.2'
ha jt
ha jt
L.C. 0.2'
NDSTONE
L.C. 0.6'
Sw
ha jt
L.C. 0.8'
so zone I
L.C. 0.2'
FOUNDING ELEVATION 416.0
RDC-18
775' RT
HALE
ha jt
ha jt
406.1
L.C. 0.1'
Og
L.C. 0.2'
la jt
L.C. 0.3'
L.C. 0.3'
L.C. 0.5'
L.C. 0.5'
L.C. 0.3'
94.3%
2 1/8"
4-4-63
OB
OB

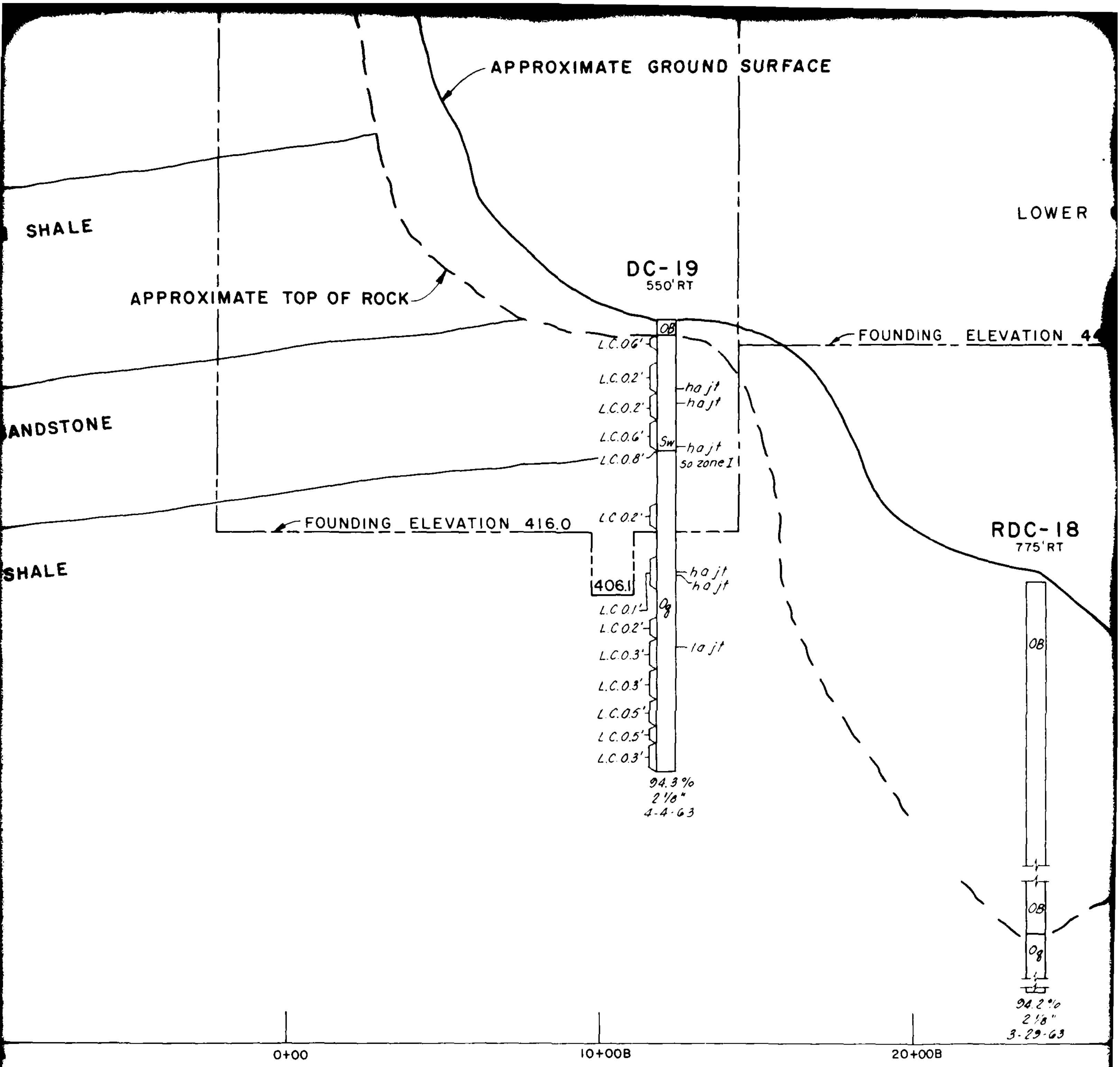


NOTE TOP OF LOCK WALL ELEVATION IS 572 0
RFACE
LOWER GUIDE WALL
FOUNDING ELEVATION 446.1
RDC-18
775'RT
OB
OB
550
540
530
520
510
500
490
480
470
460
450
440
430
420
410
400
390
380
370
290
280



ELEVATION IN FEET I.G.L.D. (1955)
490
480
470
460
450
440
430
420
410
400
390
380
370
290
280
230
bdd pln, healed w/gyp
Sg
bdd plns, healed w/gyp
h a jts, op
so zone II, 0.05
la jts, op
bdd plns, healed w/gyp
Sp
hor jt op
bdd plns, healed w/gyp
Sw
vert jt, healed
so zone I, 0.4
la jts, op, num
100 %
6"
4-11-63
POWER GLEN SHALE
WHIRLPOOL SANDSTONE
QUEENSTON SHALE
APPROXIMATE
LOCK STATION 27+42.22A
CANAL STATION 1521+06.33
20+00A
10+00A

PROFILE D-D



PROFILE D-D

NOTES:

HOLES RC-21 AND DC-19 HAVE BEEN PROJECTED AT RIGHT ANGLES TO LOCK CENTERLINE. CORRECTIONS ARE 5.6' UP FOR RC-21 AND 6.0' UP FOR DC-19.

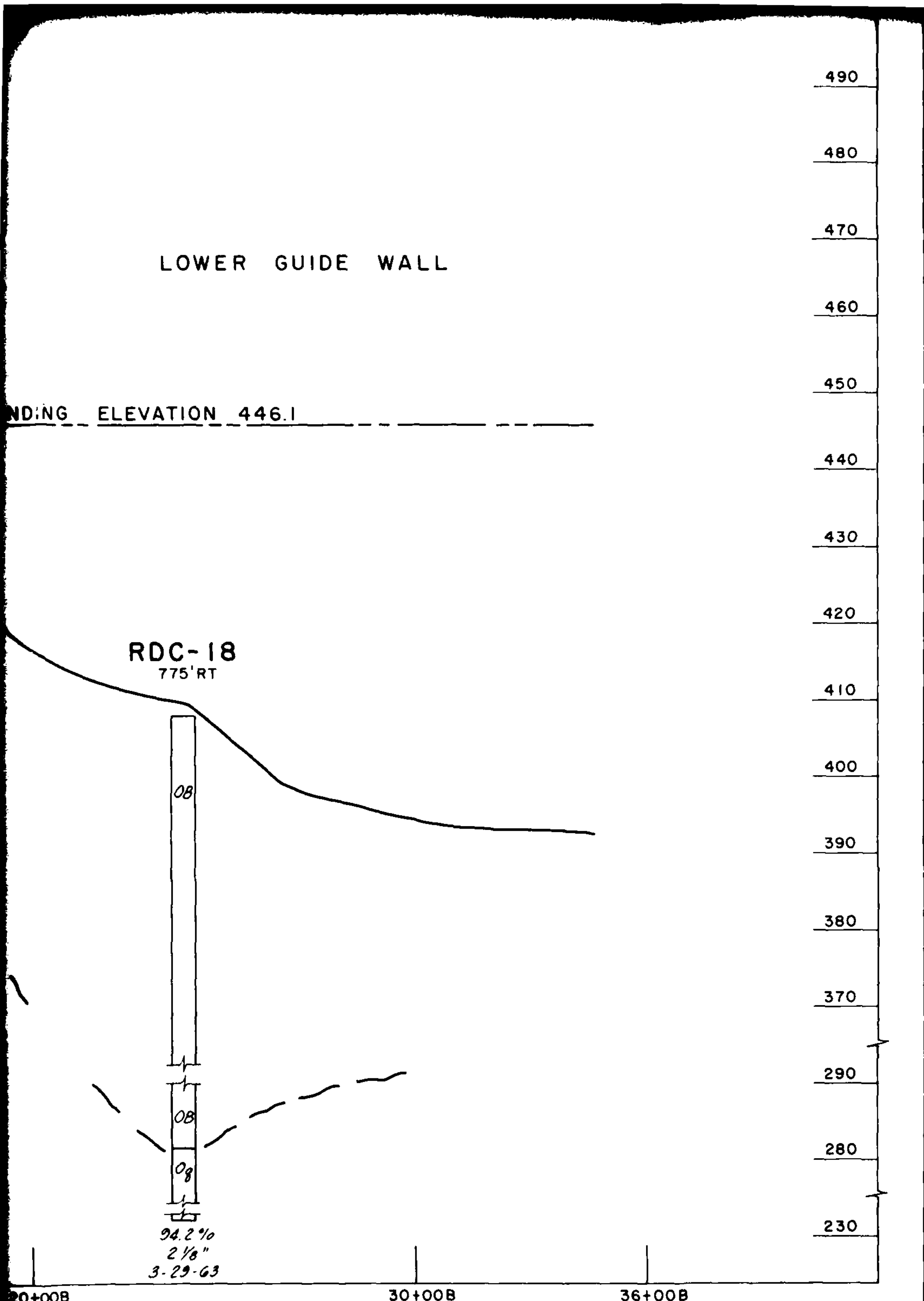
FOR LOCATION OF PROFILE AND BORINGS, SEE PLATE B3 AND B4.

FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS, JOINT CLASSIFICATIONS, AND SOFT ZONE CLASSIFICATION, SEE PLATE B1.

FOR DETAILED DESCRIPTION OF OVERBURDEN, SEE PLATES B14 AND B15.

LOCK STATIONING ALONG THE PROFILE WAS USED DUE TO THE BEND OF THE CANAL ALIGNMENT ALONG LOCK 4-5.

DETAIL INFORMATION ON BORING RDC-18 HAS NOT BEEN SHOWN ON THIS SHEET.



TERLINE. CORRECTIONS ARE

REVIATIONS, JOINT CLASSI-

ANAL ALIGNMENT ALONG

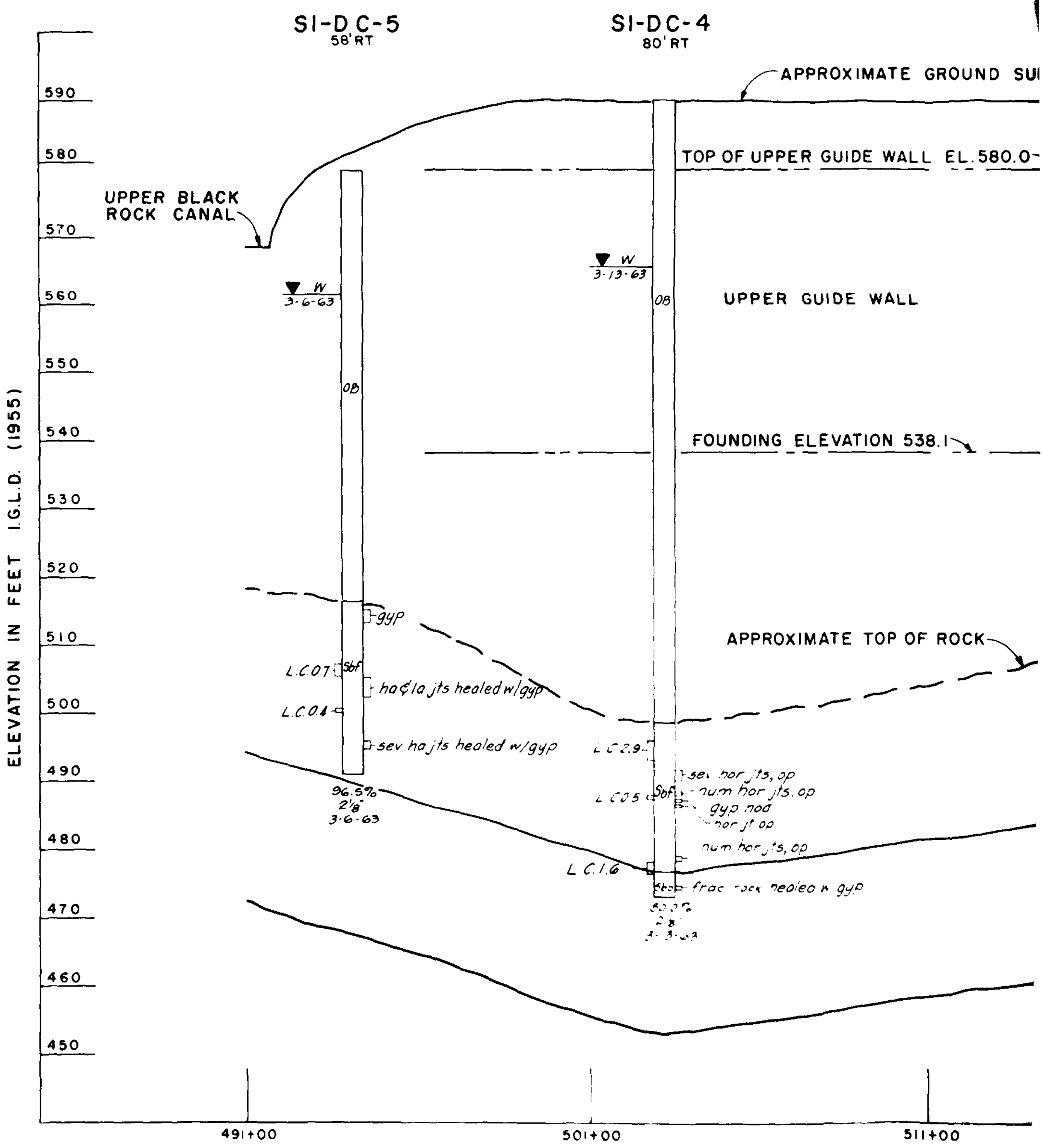
ET.

LAKE ERIE-LAKE ONTARIO WATERWAY

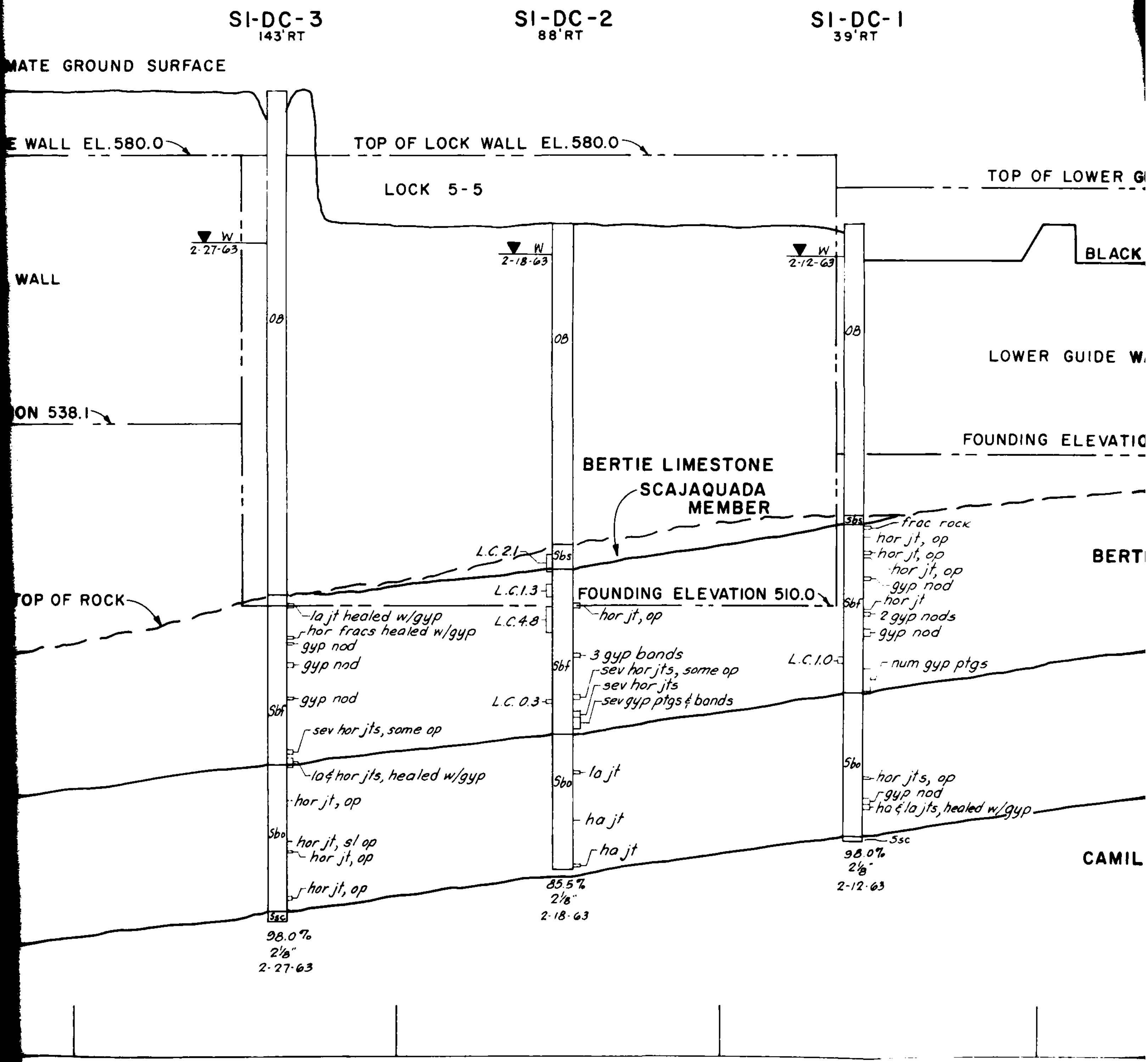
GEOLOGIC PROFILE
LOCK 4-5

U. S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

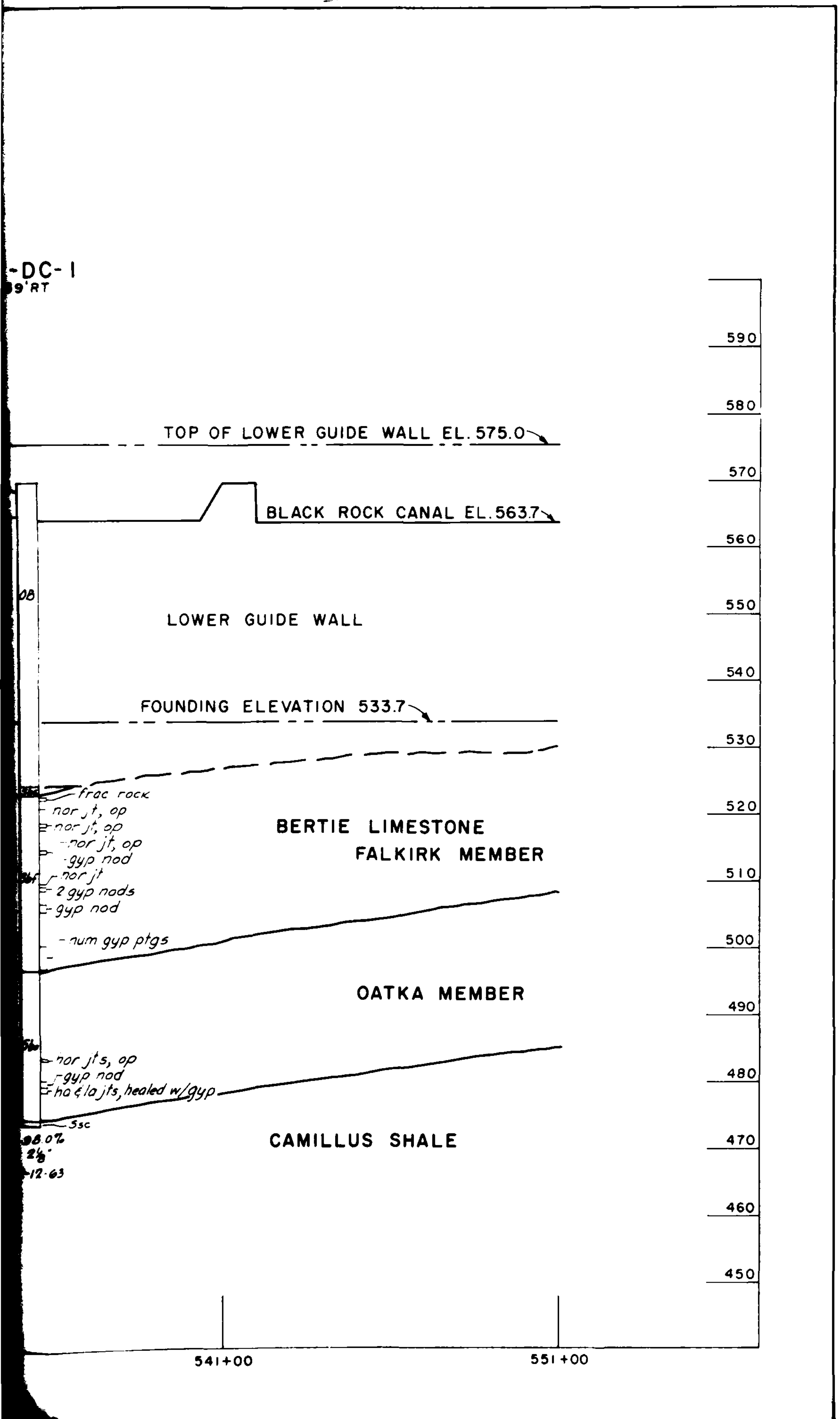


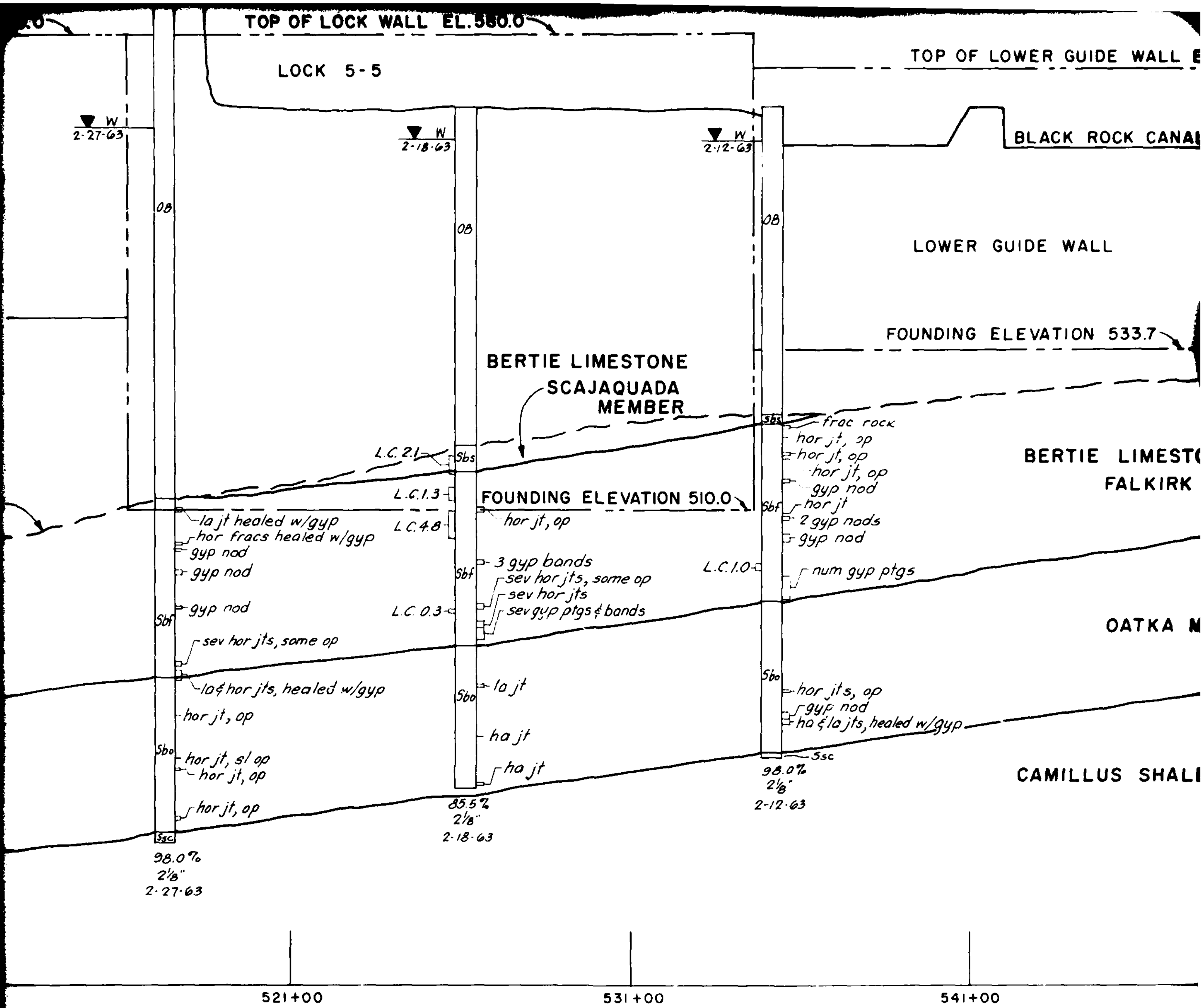
SI-DC-5
58'RT
SI-DC-4
80'RT
APPROXIMATE GROUND SU
TOP OF UPPER GUIDE WALL EL.580.0
UPPER BLACK ROCK CANAL
UPPER GUIDE WALL
FOUNDING ELEVATION 538.1
APPROXIMATE TOP OF ROCK
W 3-6-63
W 3-13-63
OB
OB
gyp
Sbf
L.C.0.7
ha & la jts healed w/gyp
L.C.0.4
sev ha jts healed w/gyp
96.5%
2 1/8"
3-6-63
L.C.2.9
sev hor jts, op
num hor jts, op
Sbf
L.C.0.5
gyp nod
hor jt op
num hor jts, op
L.C.1.6
frac rock healed w gyp
ELEVATION IN FEET I.G.L.D. (1955)
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
491+00
501+00
511+00



SI-DC-3
143' RT
SI-DC-2
88' RT
SI-DC-1
39' RT
MATE GROUND SURFACE
E WALL EL. 580.0
TOP OF LOCK WALL EL. 580.0
LOCK 5-5
TOP OF LOWER G
W
2-27-63
W
2-18-63
W
2-12-63
BLACK
WALL
OB
LOWER GUIDE W
ON 538.1
FOUNDING ELEVATIO
BERTIE LIMESTONE
SCAJAQUADA MEMBER
Sbs
frac rock
hor jt, op
hor jt, op
hor jt, op
gyp nod
hor jt
2 gyp nods
gyp nod
BERT
L.C. 2.1
L.C. 1.3
L.C. 4.8
FOUNDING ELEVATION 510.0
TOP OF ROCK
la jt healed w/gyp
hor fracs healed w/gyp
gyp nod
gyp nod
gyp nod
hor jt, op
3 gyp bands
sev hor jts, some op
sev hor jts
sev gyp ptgs & bands
L.C. 1.0
num gyp ptgs
L.C. 0.3
Sbf
sev hor jts, some op
la & hor jts, healed w/gyp
la jt
Sbo
hor jts, op
gyp nod
ha & la jts, healed w/gyp
hor jt, op
ha jt
hor jt, sl op
hor jt, op
ha jt
Ssc
CAMIL
hor jt, op
98.0%
2 1/8"
2-12-63
85.5%
2 1/8"
2-18-63
98.0%
2 1/8"
2-27-63
511+00
521+00
531+00
541+00

PROFILE E-E


-DC-1
9'RT
TOP OF LOWER GUIDE WALL EL. 575.0
BLACK ROCK CANAL EL. 563.7
LOWER GUIDE WALL
FOUNDING ELEVATION 533.7
frac rock
nor jt, op
nor jt, op
nor jt, op
gyp nod
nor jt
2 gyp nods
gyp nod
num gyp ptgs
BERTIE LIMESTONE
FALKIRK MEMBER
OATKA MEMBER
nor jts, op
gyp nod
ha & la jts, healed w/gyp
Ssc
CAMILLUS SHALE
98.0%
12-63
590
580
570
560
550
540
530
520
510
500
490
480
470
460
450
541+00
551+00



PROFILE E-E

NOTES:

FOR LOCATIONS OF PROFILES AND BORINGS SEE PLATE B6.

FOR LEGEND OF EXPLORATIONS, GENERALIZED GEOLOGIC COLUMN, LIST OF ABBREVIATIONS AND JOINT CLASSIFICATIONS SEE PLATE B1.

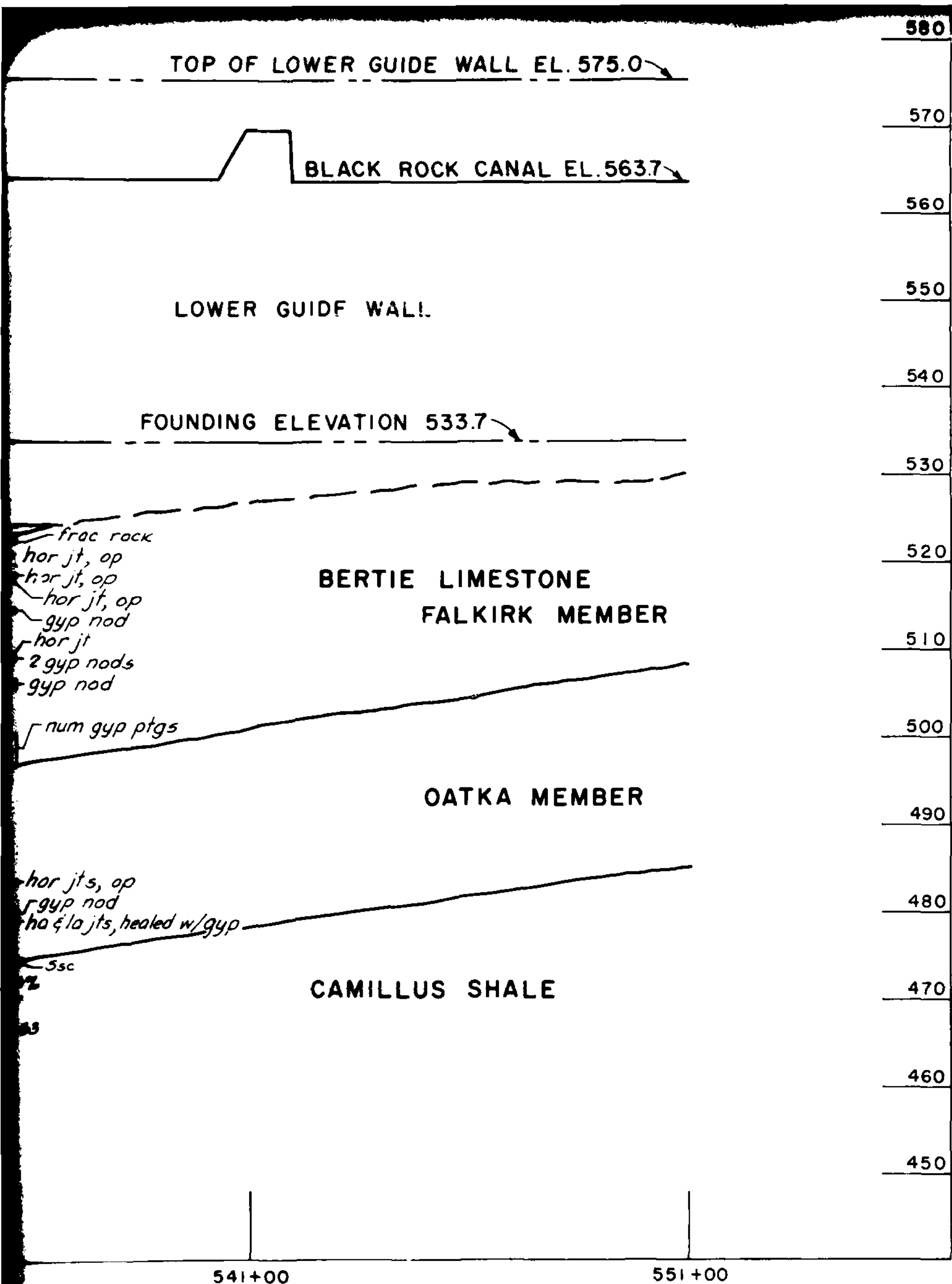
FOR DETAILED DESCRIPTION OF OVERBURDEN SEE PLATE B19.

LAKE E

G

U.S. ARMY

TO ACCOM



ND BORINGS

, GENERALIZED
IATIONS AND
81.
OVERBURDEN

LAKE ERIE-LAKE ONTARIO WATERWAY

GEOLOGIC PROFILE
LOCK 5-5

U.S. ARMY ENGINEER DISTRICT, BUFFALO

TO ACCOMPANY REVIEW OF REPORTS
OCTOBER 1973

PLATE B24

Figure B1 - View of area just west of the overland section of the proposed waterway.

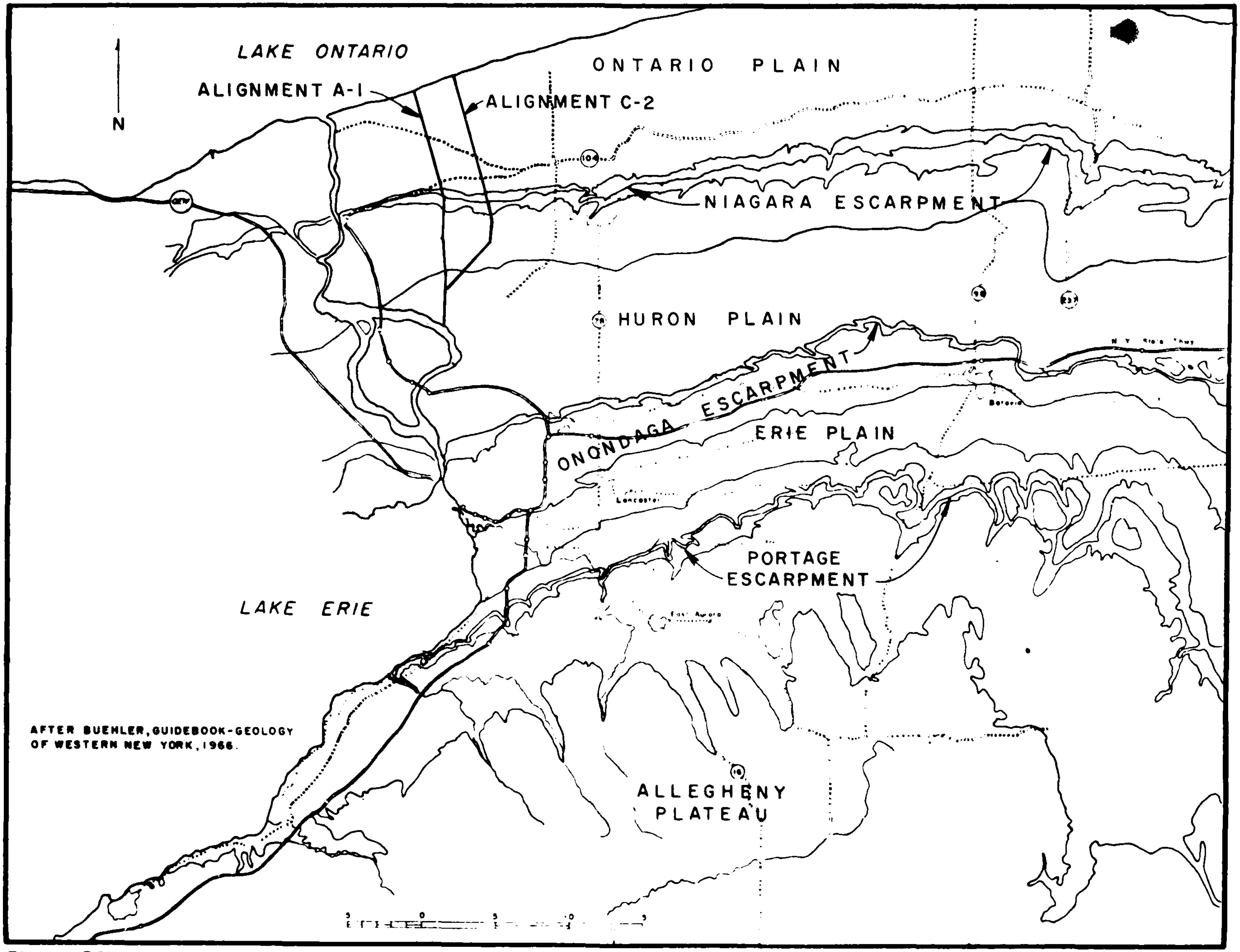


Figure B2 - Physiographic map of western New York.

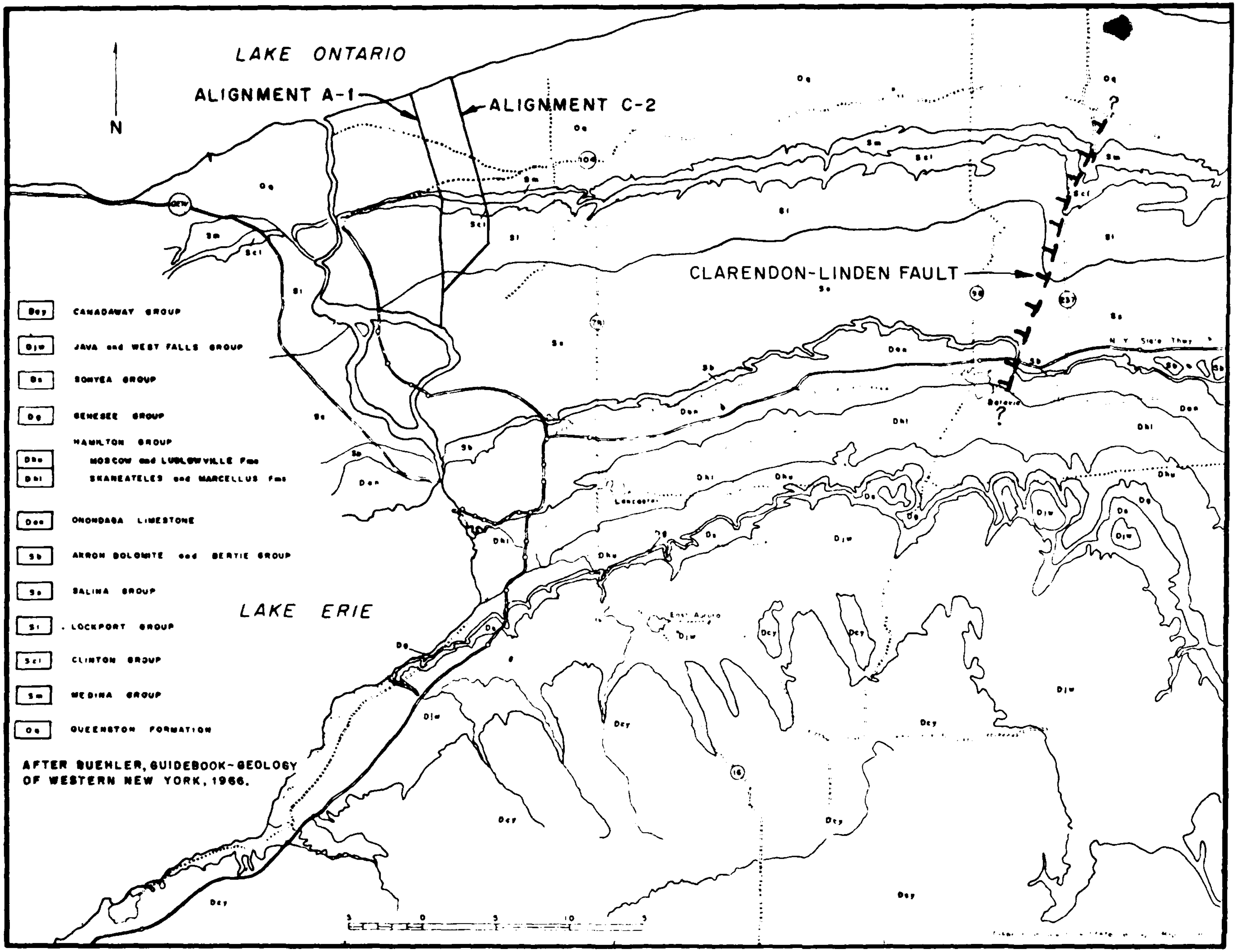
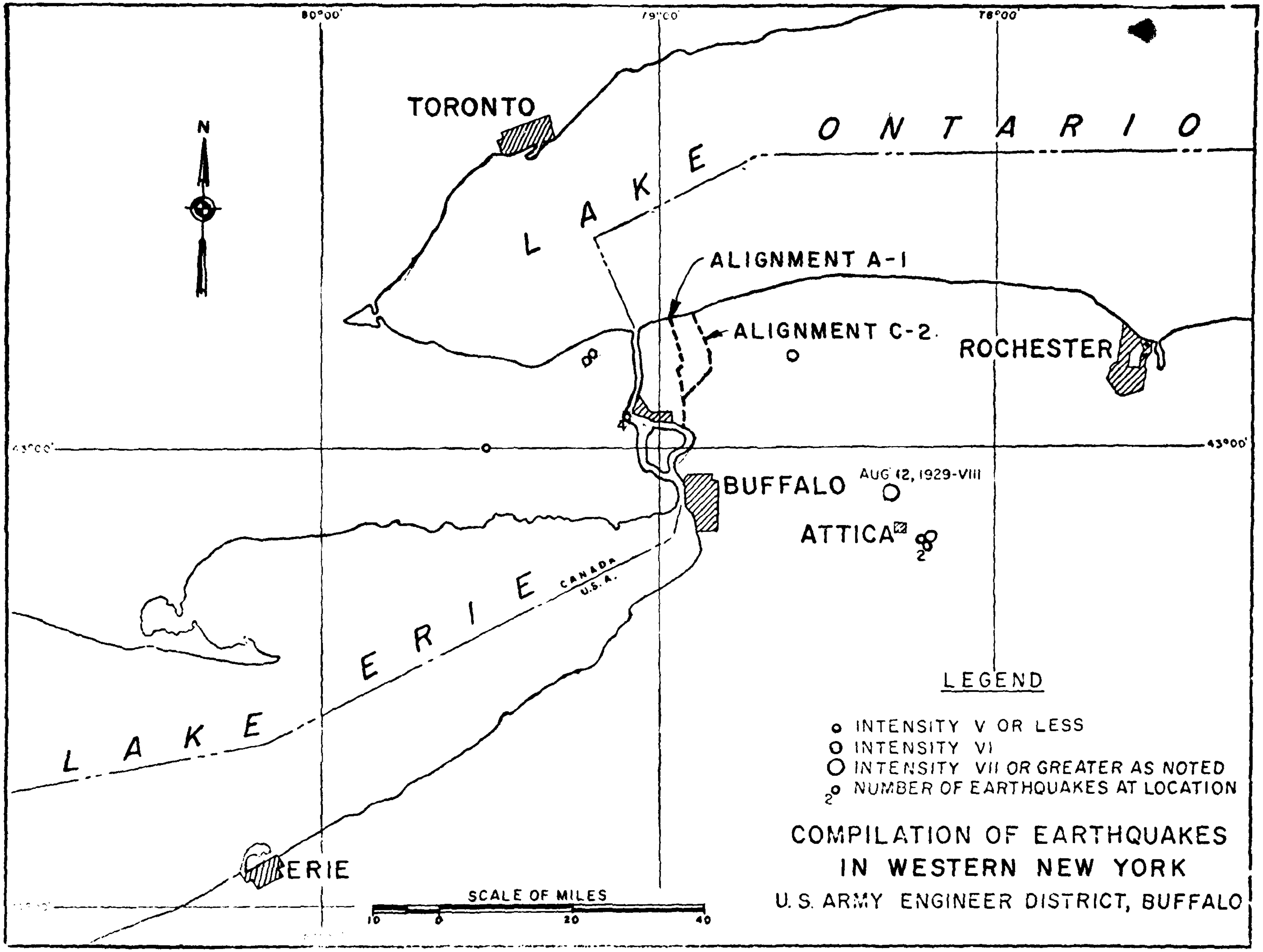


Figure B3- Geologic map of western New York.



80°00'
79°00'
78°00'
43°00'
N
TORONTO
LAKE ONTARIO
ALIGNMENT A-1
ALIGNMENT C-2
ROCHESTER
BUFFALO
AUG 12, 1929-VIII
ATTICA
2
LAKE ERIE
CANADA
U.S.A.
ERIE
SCALE OF MILES
10
0
20
40
LEGEND
INTENSITY V OR LESS
INTENSITY VI
INTENSITY VII OR GREATER AS NOTED
2 NUMBER OF EARTHQUAKES AT LOCATION
COMPILATION OF EARTHQUAKES
IN WESTERN NEW YORK
U.S. ARMY ENGINEER DISTRICT, BUFFALO

Figure B4

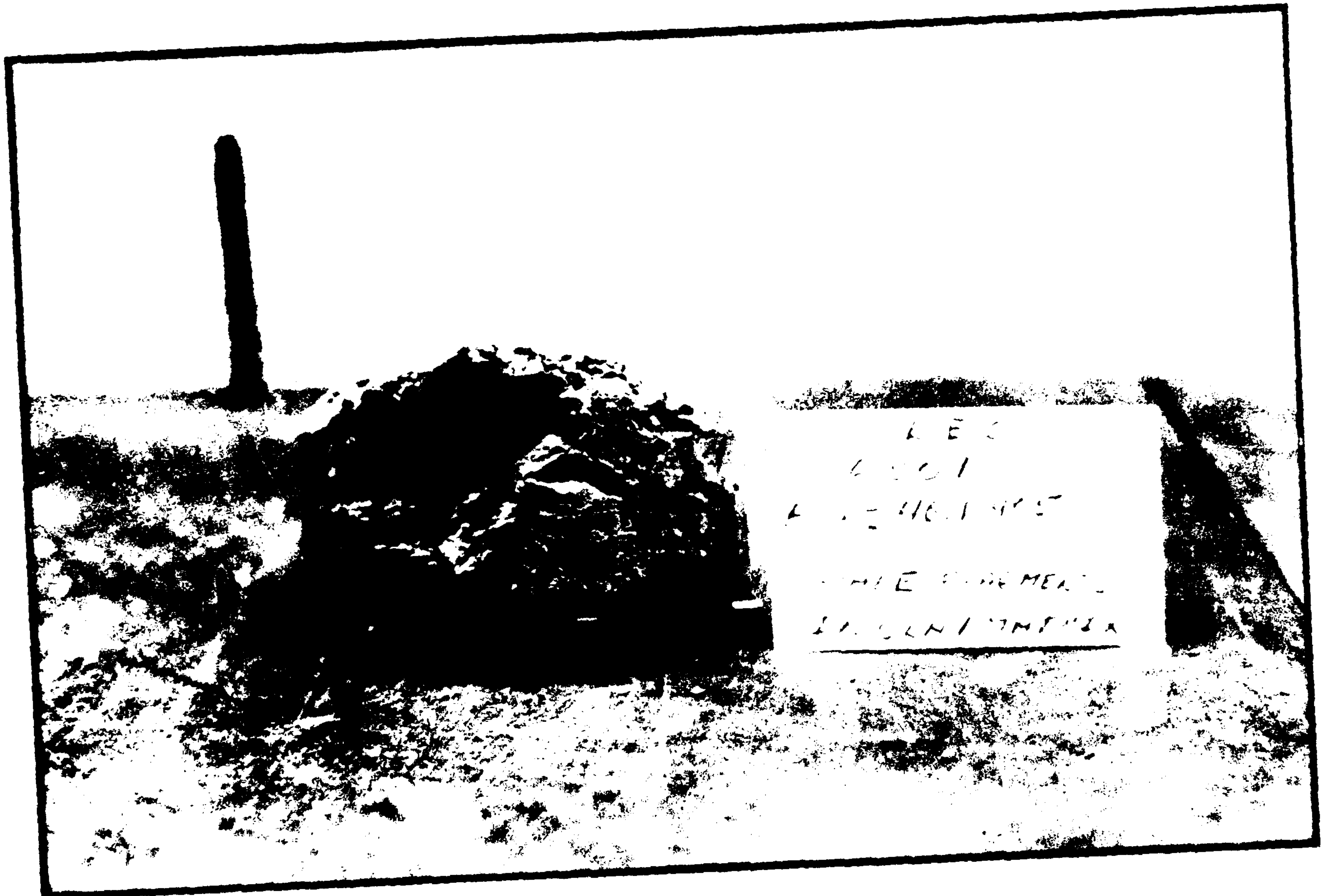


Figure B5 - Soft zone and shale fragments found in core of Queenston Shale.

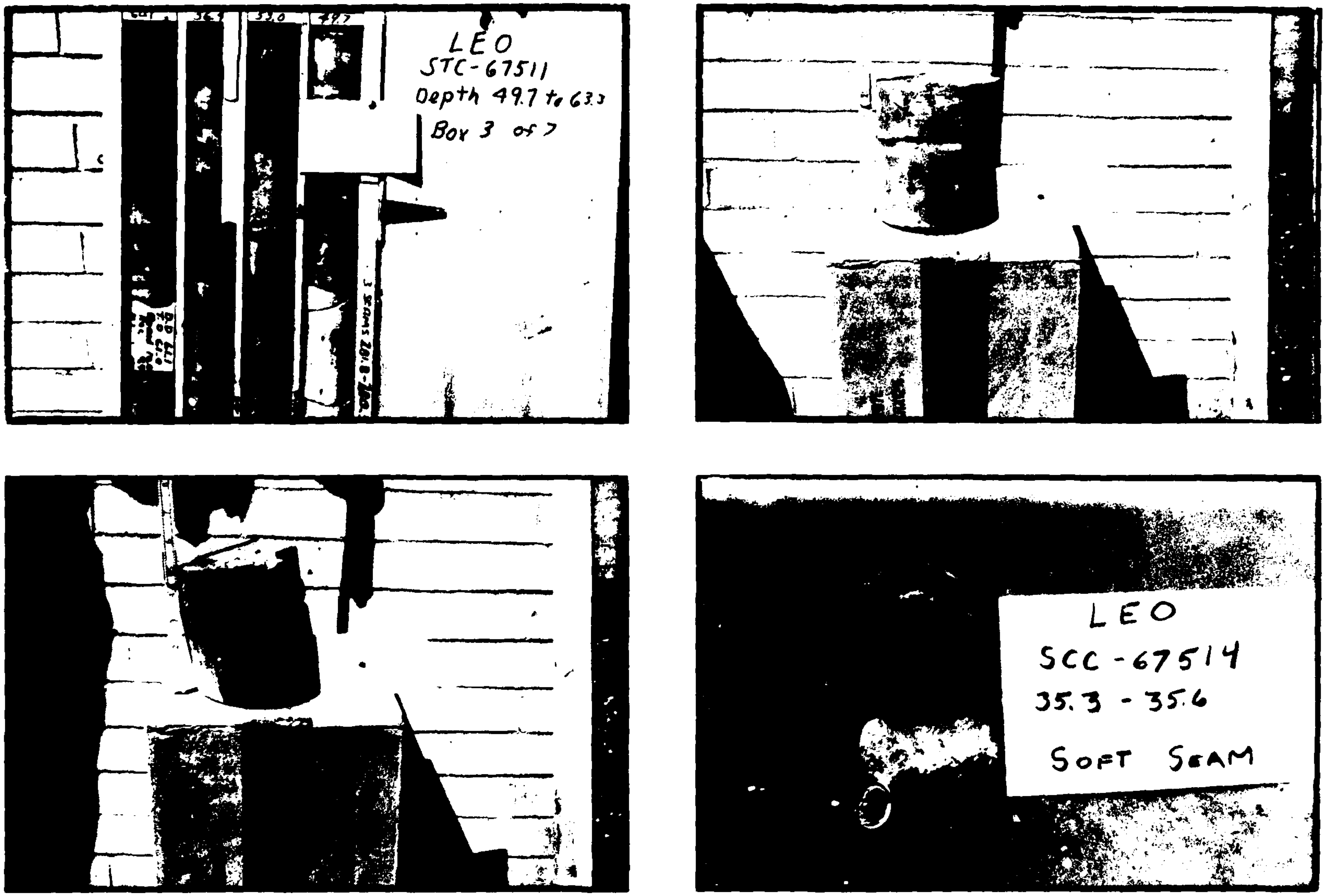


Figure B6 - Typical soft zones found in core of Queenston Shale.

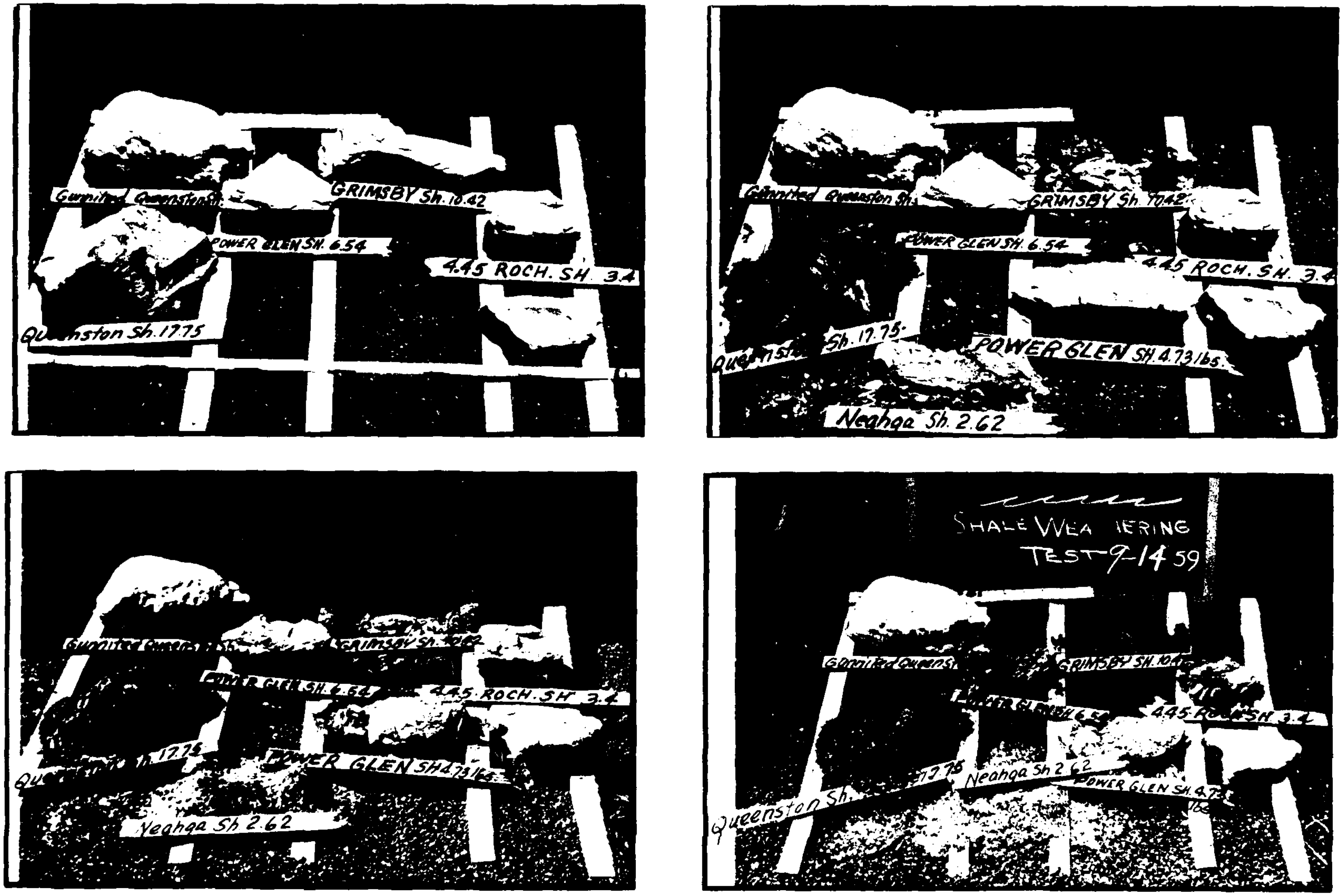


Figure B7 - Shale weathering test - Breakdown of exposed shale formations due to atmospheric conditions. (Note dates on blackboard)

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